LAURI NYRHI

Fractures and Orthopaedic Disorders During Pregnancy and the Following Recovery Period

An epidemiologic nationwide register study
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An epidemiologic nationwide register study

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ABSTRACT

Mothers experience various physiological changes both during pregnancy and the postpartum period that make them more vulnerable to the orthopaedic disorders caused by altered bone, connective tissue and hormonal metabolism. Since these conditions have significant effects on both the mother and the developing foetus, they require special attention. Although there have been several case reports and series on the epidemiology of orthopaedic disorders during pregnancy, no large-scale studies have been conducted thus far.

To fill this knowledge gap, we carried out a retrospective cohort study based on data from two Finnish national registries. The study aimed to analyse the incidence of common orthopaedic disorders during pregnancy and the first year after delivery. We collected data on orthopaedic trauma and operations for all women aged 15 to 49 years as well as on all pregnancies in Finland over a 21-year period from 1 January 1998 to 31 December 2018. We created age-adjusted cohorts of orthopaedic disorders occurring during pregnancy or the first postpartum year, and outside of these periods. We used logistic regression models and Kaplan-Meier survival analysis for statistical analysis and included data on maternal smoking as a risk factor for events.

In study I, we analysed the incidence of fracture hospitalisation and fracture surgery during pregnancy. Pelvic trauma and rates of perinatal mortality were studied separately. Similar data for fractures occurring during the first postpartum year were analysed in study II. Traumatic ruptures of the pubic symphysis occurring after vaginal delivery were analysed separately in study III. In study IV, we analysed the incidence of lumbar discectomy during pregnancy and the first postpartum year. Similar incidences regarding peripheral nerve decompression surgery were analysed separately in study V.

The main findings of our study were that the incidence of fractures during pregnancy (study I) was lower than in the normal female population
of the same age (IRR 0.34, CI 0.33 to 0.34). The total fracture incidence was 247 fractures per 100 000 pregnancy-years (95% CI 237 to 259) leading to hospitalisation during pregnancy. Of these, about one fifth required operative treatment resulting in an incidence of 61 operations per 100 000 pregnancy-years (CI 56 to 67). After delivery (study II), the total incidence of fractures leading to hospitalisation during the first 12 months after delivery was 280 fractures per 100 000 person-years (95% CI 270 to 290) with one fourth of these fractures requiring operative treatment. Incidences of pelvic fractures during the first 4 months postpartum were similar to those in the normal population, but otherwise all rates remained lower. Traumatic ruptures of the pubic symphysis following vaginal birth (study III) occurred at a rate of 0.8 ruptures per 100 000 deliveries (CI 0.4 to 1.5).

For lumbar discectomy (study IV), the cumulative incidence during pregnancy was 11 operations per 100 000 person-years and 47 operations per 100 000 person-years during the first postpartum year. For pregnant women, the immediate reoperation rate was lower than the normal population with an IRR of 0.5 (CI 0.4 to 0.6), but higher during the first 12 months after pregnancy with an IRR of 1.7 (CI 1.1 to 2.7). Maternal smoking before pregnancy increased the risk of lumbar discectomy during pregnancy.

For peripheral nerve decompression surgery (study V) the most common procedure was carpal tunnel release (CTR), as only isolated cases of other operations were performed. The total incidence of CTR during pregnancy was lower than in the normal population with 38 operated women per 100 000 person-years (IRR 0.5, CI 0.4 to 0.6). After delivery, the incidence rose to 63 operated women per 100 000 person-years in the first postpartum year (IRR 0.8, CI 0.7 to 1.0). The risk of CTR during and after pregnancy was higher for women who actively smoked before pregnancy.

According to the results of our study, pregnant women sustain fewer fractures on a nationwide level when compared to similar aged women in the normal population. This phenomenon continues until at least the end of the first postpartum year. Despite this, the share of operative treatment for fractures is similar to that of the normal population. Interestingly, women are less likely to undergo lumbar discectomy and CTR, especially during pregnancy. One possible explanation for this is that surgeons may be more hesitant to perform operations during pregnancy due to concerns about the safety of the foetus.
Raskauden aikaiset fysiologiset muutokset ovat moninaisia ja altistavat äidin luuston, sidekudoksen ja hormonaalisen aineenvaihdunnan muutosten vuoksi useille ortopedisille ongelmille sekä raskauden aikana että sitä seuraavan toipumisjakson aikana. Ortopediset ongelmat raskauden aikana ovat myös hoidollisesti haasteellisia, koska ne vaikuttavat sekä äitiin että kehittyvään sikiöön. Vaikka aiheesta on julkaistu lukuisia tapausselostuksia sekä potilassarjoja, ei laajamittaisia epidemiologisia tutkimuksia aiheesta ole tähän mennessä julkaistu.


Osatyössä I analysoimme murtumien sairaalahoito- ja murtumaleikkausilmaantuvuuutta raskauden aikana. Vastaava ilmaantuvuus ensimmäisen synnytyksen jälkeisen vuoden aikana tapahtuvista murtumista analysoitiin osatyössä II. Alatiesynnytyksen jälkeisten symfyysirepeämien ilmaantuvuutta tutkiin erikseen osatyössä III. Osatyössä IV analysoimme lannerangan välilevykirurgian ilmaantuvuutta raskauden aikana ja ensimmäisen synnytyksen jälkeen. Vastaavaa ilmaantuvuutta koskienääreishermojen dekompressioleikkausia analysoitiin erikseen osatyössä V.

Tutkimuksemme tärkeimmät löydökset olivat seuraavat. Murtumien ilmaantuvuus raskauden aikana (osatyö I) oli alhaisempi kuin saman ikäisillä
normaaliväestöön kuuluvilla naisilla (IRR 0.34, lv 0.33-0.34). Sairalahoitoisten murtumien kokonaisilmaantuvuus oli 247 murtumaa 100 000 raskausvuotta kohti (lv 237-259). Näistä noin viidesosa vaati leikkaushoitoa ilmaantuvuudella 61 leikkausta 100 000 raskausvuotta kohti (lv 56-67). Ensimmäisen synnytyksen jälkeisen vuoden (tutkimus II) sairaalahoitoisten murtumien kokonaisilmaantuvuus oli 280 murtumaa 100 000 henkilövuotta kohti (lv 270-290), joista neljännes vaati leikkaushoitoa. Lantion murtumien esiintyvyys ensimmäisen 4 kuukauden aikana synnytyksen jälkeen oli vastaava kuin normaaliväestössä, mutta muutuin ilmaantuvuudet läpi linjan pysyivät normaaliväestöä matalampina. Alatiesynnytyksen jälkeisten symfyysirepeämien (tutkimus III) ilmaantuvuus oli 0,8 repeämää 100 000 synnytystä kohti (lv 0,4-1,5).

Lannerangan välilevyleikkausten kokonaisilmaantuvuus raskaudessa aikana oli 11 leikkausta 100 000 henkilövuotta kohden ja ensimmäisen synnytyksen jälkeisenä vuonna 47 leikkausta 100 000 henkilövuotta kohden (tutkimus IV). Raskaana olevilla naisilla oli pienempi välittömän uusintaleikkausen riski kuin normaaliväestöllä (IRR 0,5, lv 0.1-3.5), mutta suurempi ensimmäisen synnytyksenjälkeisen vuoden aikana (IRR 1,7, lv 1.1-2.7). Äidin tupakointi ennen raskautta lisäsi lannerangan välilevyleikkauskseen riskiä raskaudessa aikana. Perifeeristen hermojen dekompressioleikkausten joukossa (tutkimus V) yleisin toimenpide oli rannekanavan vapautus. Muita vapaustusleikkauskia havaittiin vain yksittäistapauksina. Rannekanavan vapaustisten kokonaisilmaantuvuus raskaudessa aikana oli 38 leikattua naista 100 000 henkilövuotta kohden, jääden normaaliväestöä matalammaksi (IRR 0.5, lv 0.4-0.6). Synnytyksen jälkeen ilmaantuvuus nousi 63 leikattuun naiseen 100 000 henkilövuotta kohden ensimmäisenä synnytyksen jälkeisenä vuonna (IRR 0.8, lv 0.7-1.0). Rannekanavan leikkauskseen riski raskaudessa aikana ja sen jälkeen oli korkeampi naisilla, jotka tupakoivat aktiivisesti ennen raskautta.

Tutkimustuloksemme osoittavat äitien saavan väestötasolla vähemmän murtumia muuhun saman ikäiseen naisväestöön verrattuna vielä jopa vuoden ajan synnytyksen jälkeen. Siitä huolimatta leikkaushoidon kriteerit vaikuttavat olevan yhteneväiset, sillä toimenpiteiden osuus oli vastaava kuin normaaliväestöllä. Lannerangan välilevyleikkausten ja rannekanavan vapaustisten osalta äitejä leikataan painvastoin harvemmin, erityisesti raskaudessa aikana. Leikkaushoitoa harkittaessa komplikaatioriskit saattavatkin korostua niiden vaikutusten kohdistuessa myös sikiöön.
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## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACOG</td>
<td>American College of Obstetricians and Gynecologists</td>
</tr>
<tr>
<td>AP</td>
<td>Anteroposterior view</td>
</tr>
<tr>
<td>APC</td>
<td>Anteroposterior compression</td>
</tr>
<tr>
<td>CI</td>
<td>95% Confidence intervals</td>
</tr>
<tr>
<td>CT</td>
<td>Computerised tomography</td>
</tr>
<tr>
<td>CTF</td>
<td>Combined Task Force</td>
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<tr>
<td>CTS</td>
<td>Carpal tunnel syndrome</td>
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<tr>
<td>CTR</td>
<td>Carpal tunnel release</td>
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<tr>
<td>EMG</td>
<td>Electromyography</td>
</tr>
<tr>
<td>ICD-10</td>
<td>International Classification of Diseases 10th version</td>
</tr>
<tr>
<td>IRR</td>
<td>Incidence rate ratio</td>
</tr>
<tr>
<td>LC</td>
<td>Lateral compression</td>
</tr>
<tr>
<td>LDH</td>
<td>Lumbar disc herniation</td>
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<tr>
<td>MBR</td>
<td>Medical Birth Register</td>
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<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
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<tr>
<td>NCS</td>
<td>Nerve conduction study</td>
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<tr>
<td>NOMESCO</td>
<td>Nordic Medico-Statistical Committee</td>
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<tr>
<td>OPG</td>
<td>Osteoprotegerin</td>
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<tr>
<td>OR</td>
<td>Odds ratio</td>
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<tr>
<td>PAO</td>
<td>Pregnancy-associated osteoporosis</td>
</tr>
<tr>
<td>PLO</td>
<td>Pregnancy and lactation induced osteoporosis</td>
</tr>
<tr>
<td>PPGP</td>
<td>Pregnancy-related pelvic girdle pain</td>
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<tr>
<td>PRCTS</td>
<td>Pregnancy-related carpal tunnel syndrome</td>
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<tr>
<td>PTH</td>
<td>Parathyroid hormone</td>
</tr>
<tr>
<td>PTHrP</td>
<td>Parathyroid hormone-related protein</td>
</tr>
<tr>
<td>RANK</td>
<td>Nuclear factor kappa-B</td>
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<tr>
<td>RANKL</td>
<td>RANK-ligand</td>
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<tr>
<td>SD</td>
<td>Standard deviation</td>
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<tr>
<td>SLR</td>
<td>Straight leg raise-test</td>
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<tr>
<td>STROBE</td>
<td>Strengthening the Reporting of Observational Studies in Epidemiology</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>THL</td>
<td>Finnish Institute of Health and Welfare</td>
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<tr>
<td>TLICS</td>
<td>Thoracolumbar Injury Classification and Severity Score</td>
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<tr>
<td>TOP</td>
<td>Transient osteoporosis of pregnancy</td>
</tr>
<tr>
<td>VS</td>
<td>Vertical shear</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation</td>
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<tr>
<td>XSLR</td>
<td>Crossed straight leg raise-test</td>
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This dissertation is based on the following publications referred to in the text by their Roman numerals I to V.

**Publication I**

**Publication II**

**Publication III**

**Publication IV**
Nyrhi Lauri, Kuitunen Ilari, Ponkilainen Ville, Mäntymäki Heikki, Huttunen Tuomas, Mattila Ville. Incidence of lumbar discectomy during pregnancy and within 12 months post-partum in Finland between 1999 and 2017: a retrospective
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Publication IV  **Nyrhi Lauri**, Kuitunen Ilari, Ponkilainen Ville, Mäntymäki Heikki, Huttunen Tuomas, Mattila Ville. Incidence of lumbar discectomy during pregnancy and within 12 months post-partum in Finland between 1999 and 2017: a retrospective
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AUTHOR’S CONTRIBUTIONS

Publication I  Lauri Nyrhi collaborated in devising the study design, conducted appropriate statistical analyses, interpreted the results and wrote the initial manuscript. Lauri Nyrhi was the corresponding author of this manuscript.

Publication II  Lauri Nyrhi collaborated in devising the study design, conducted appropriate statistical analyses, interpreted the results and wrote the initial manuscript. Lauri Nyrhi was the corresponding author of this manuscript.

Publication III  Lauri Nyrhi conducted appropriate statistical analyses, interpreted the results and wrote the initial manuscript. Lauri Nyrhi was the corresponding author of this manuscript.

Publication IV  Lauri Nyrhi collaborated in devising the study design, conducted appropriate statistical analyses, interpreted the results and wrote the initial manuscript. Lauri Nyrhi was the corresponding author of this manuscript.

Publication V  Lauri Nyrhi collaborated in devising the study design, conducted appropriate statistical analyses, interpreted the results and wrote the initial manuscript. Lauri Nyrhi was the corresponding author of this manuscript.
Pregnancy is one of the most emotionally and physiologically demanding experiences of a woman's life, and thus medical conditions occurring during this period are challenging for both the mother and the physician. Hormonal changes during pregnancy (especially changes in relaxin and oestrogen) induce changes of collagen and bony metabolism which, along with increased body mass and fluid build-up, make the expectant mother more susceptible to conditions of the musculoskeletal system. A dreaded condition during pregnancy that causes severe morbidity are fractures of the pelvic area. It has been estimated that varying degrees of trauma complicate one in twelve pregnancies. Moreover, foetal death due to maternal trauma has been estimated to have an incidence of 2.3 per 100 000 live births. Pelvic fractures have been estimated to have a rate of 35% foetal and 9% maternal mortality.

One of the most common complaints during pregnancy is lower back pain with an estimated prevalence of 50% to 70%. (F. M. Kovacs et al., 2012; S.-M. Wang et al., 2004) More severe instability of the pelvic ring involving the symphysis with painful disability has been described in 25% of pregnancies. (Wu et al., 2004) However, the incidence of lumbar disc herniations have only been evaluated in case series where an incidence of 10 per 100 000 pregnancies has been reported. (LaBan et al., 1983) The incidence of pubic symphysis ruptures has previously been described in a single report for 1/385 pregnancies. (J. J. Yoo et al., 2014) As almost as frequent an entity as lower back pain, 62% of pregnant women are reported to have carpal tunnel syndrome (CTS) during pregnancy. (Bahrami et al., 2005; Khosrawi & Maghrouri, 2012; L. Padua et al., 2001; Stolp-Smith et al., 1998) However, previous reports describing the epidemiology of surgical treatment for carpal tunnel syndrome during pregnancy are lacking.

Despite all the above mentioned conditions being common and affecting pregnancies daily, no large-scale epidemiological studies exist on any of the maternal fractures or lumbar discectomies of carpal tunnel syndrome during pregnancy. In this dissertation, the focus was on providing novel...
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One of the most common complaints during pregnancy is lower back pain with an estimated prevalence of 50% to 70%. (F. M. Kovacs et al., 2012; S.-M. Wang et al., 2004) More severe instability of the pelvic ring involving the symphysis with painful disability has been described in 25% of pregnancies. (Wu et al., 2004) However, the incidence of lumbar disc herniations have only been evaluated in case series where an incidence of 10 per 100 000 pregnancies has been reported. (LaBan et al., 1983) The incidence of pubic symphysis ruptures has previously been described in a single report for 1/385 pregnancies. (J. J. Yoo et al., 2014) As almost as frequent an entity as lower back pain, 62% of pregnant women are reported to have carpal tunnel syndrome (CTS) during pregnancy. (Bahrami et al., 2005; Khosrawi & Maghrouri, 2012; L. Padua et al., 2001; Stolp-Smith et al., 1998) However, previous reports describing the epidemiology of surgical treatment for carpal tunnel syndrome during pregnancy are lacking.

Despite all the above mentioned conditions being common and affecting pregnancies daily, no large-scale epidemiological studies exist on any of the maternal fractures or lumbar discectomies of carpal tunnel syndrome during pregnancy. In this dissertation, the focus was on providing novel
nationwide epidemiological data on fractures and other common orthopaedic conditions of pregnancy when compared to the non-pregnant female population. The aim was to analyse epidemiology from an orthopaedic standpoint, and thus for orthopaedic conditions to focus on the epidemiology of operative treatment. For fractures, the aim was to provide general fracture epidemiology and to provide integral perinatal statistics for fractures of the lumbopelvic region. Since the effects of pregnancy on the female body last well into the first year following delivery, we included this period in our study to assess the epidemiological changes as mothers return to normal life.
2 REVIEW OF THE LITERATURE

2.1 Pregnancy, lactation and the musculoskeletal system

2.1.1 Hormonal and physiological changes during pregnancy

During pregnancy, a woman’s body undergoes several biological and physiological changes, which slowly recover after pregnancy. Due to increased mass and hormonal activity, the body is put through unprecedented stress. Indeed, previous studies have revealed that almost all women (>90%) suffer from some kind of musculoskeletal condition during pregnancy and at least one quarter a temporarily incapacitating one. (Heckman & Sassard, 1994; Ramachandra et al., 2015) However, many of the changes experienced by women during pregnancy are absolutely necessary for safe parturition to proceed. (O D Sherwood et al., 1993)

The main hormones associated with physiological changes during pregnancy have been found to be relaxin, progesterone and oestrogen with circulating relaxin having the most effect on the musculoskeletal system. (Dehghan et al., 2014) First discovered in 1926, relaxin is an insulin-like polypeptide hormone. (Hisaw, 1926) To date, seven known peptides of the relaxin-family (RLX) have been discovered. (Bathgate et al., 2013) In humans, relaxin concentrations are known to rise slowly and peak in the third trimester, with lower concentrations in the third trimester associated with premature labour. (Szachter et al., 1982) Most in-vivo studies regarding the physiological role of relaxin are based on date from non-suitable non-primate experiments, and the differences between species have been well documented. (O David Sherwood, 2004) In rats, relaxin has been found to be secreted both locally from the decidua and placenta and systemically from the corpus luteum. (Dehghan et al., 2014) Undetectable levels of relaxin in pregnant human females with uterine failure and in-vitro induced fertilisation have been used to support the theory of similar secretion pathways in humans. (Conrad & Baker, 2013; Goldsmith & Weiss,
2009) Of all the known relaxin-family peptides, relaxin 1 (RLX1) and relaxin 2 (RLX2) have been associated with pregnancy-related hemodynamic changes as well as the weakening of pelvic ligaments in guinea pigs and mice. (O D Sherwood et al., 1993) In the literature concerning the effects of relaxin, its subtype is rarely reported. (Dehghan et al., 2014) Progesterone is secreted by the corpus luteum until the 11th week of gestation. (Csapo et al., 1973) Thereafter, the fetoplacental unit begins the secretion of progesterone straight into placental circulation. (Schneider et al., 1993) Moreover, progesterone also acts as an important mediator in preparing the endometrium for implantation and for regulating the maternal immunologic response to foetal antigens. (Czyzyk et al., 2017) Oestrogen is produced in the ovaries and placenta during pregnancy. While levels of oestrogen produced by the ovaries remain stable, secretion levels of both oestrogen and progesterone from the placenta increase as pregnancy proceeds. (Kumar & Magon, 2012) While oestrogen and progesterone levels quickly fall after delivery, it takes from 3 days to up to 3 months from delivery for relaxin levels to normalise. (Kristiansson et al., 1996; MacLennan et al., 1986) (Figure 1)

![Figure 1. Relative concentrations of pregnancy related circulating hormones and their fluctuations respective to pregnancy weeks.](image-url)
The systemic effects of relaxin, such as the weakening of pelvic ligaments, are possibly due to its collagenolytic effect mediated by the discharge of several tissue remodelling enzymes such as collagenase and plasminogen activator, and matrix metalloproteinases (MMPs). (Granström et al., 1992; Koay et al., 1983; Qin et al., 1997; Wiqvist et al., 1984) Higher levels of relaxin have been shown to be associated with increased pelvic girdle pain in pregnant women. (MacLennan et al., 1986) While relaxin has been shown to immunohistochemically bind to ligaments and promote ligament laxity during pregnancy, clinical presentations of increased hypermobility during pregnancy have not been shown to correlate with higher relaxin levels. (Dragoo et al., 2011; Lubahn et al., 2006; Schaubberger et al., 1996) Relaxin treatment in female pigs has been shown to lead to a weakened anterior cruciate ligament, which is visible as radiographic anterior tibial translation. (Dragoo et al., 2009) Injuries of the anterior cruciate ligament have also been shown to occur more frequently midcycle when oestrogen and relaxin levels are at their highest. (Wojtys et al., 2002) Relaxin has also been reported to effect tendon laxity through collagenase activity. (Pearson et al., 2011; Wood, Luthin, et al., 2003) The fibroblasts and the endothelium of the blood vessels of the anterior cruciate ligament have also been found to express oestrogen and progesterone receptors in humans, while higher oestradiol concentrations have been associated with impaired collagen synthesis in rabbits, suggesting a role for oestrogen in ligamentous injuries. (Liu et al., 1996, 1997) Relaxin has also been demonstrated to play a key role in regulating the collagen metabolism of the pubic symphysis in rats and mice by reducing collagen levels during pregnancy. (Hashem et al., 2006; Samuel et al., 1998; W. Wang et al., 2009)

In addition to the hormonal effects of pregnancy, the parturient goes through several other physiological changes during pregnancy. Mean maternal weight gain has been shown to be around 11 kg, mostly comprised of the enlarged uterus, foetus and breasts, but also due to increased blood volume and the build-up of extracellular fluid. (Dawes & Grudzinskas, 1991) During normal pregnancy, extracellular fluid increases by 4 to 6 litres of which at least 2 to 3 litres are interstitial. (Davison, 1997)

Musculoskeletal conditions arise from both increased ligament laxity and weight gain during pregnancy, reaching their peak towards delivery. Other changes during pregnancy include the abdominal muscles stretching to
their elastic limit towards the end of pregnancy. A study by Sperstad et al. in 2016, reported the central linea alba splits causing diastasis recti having a prevalence of 60% at 6 weeks postpartum. Increased fluid mass can also lead to peripheral oedema causing nerve entrapment. Peripheral nerve compression symptoms have been shown to correlate with clinical swelling. (de la Fuente Fonnest & Ellitsgaard, 1998; Klein, 2013) The growing uterus shifts the centre of gravity causing the pelvis to tilt anteriorly, promoting lumbar lordosis and causing increased axial load on the lumbar spine and sacroiliac joints. (Ritchie, 2003) (Figure 2) Pregnancy is also associated with a permanent loss of foot arch height, especially on the medial side with foot lengthening. (Segal et al., 2013) Some studies have, however, challenged this finding. (Dunn et al., 2012; Jelen et al., 2005)

![Figure 2. A visual illustration of pregnancy-related changes in the pelvis and lumbar spine](image-url)
2.1.2 Bone metabolism during pregnancy and lactation

During pregnancy, the need for calcium intake increases so that the mother can meet the demands of the growing foetus. These demands are met during pregnancy by increased calcium intake and increased intestinal calcium absorption. However, some bone resorption also occurs, especially with calcium-deficient diets. (C. S. Kovacs & Kronenberg, 1997; C. S. Kovacs & Ralston, 2015) Both oestrogen and relaxin play a role in regulating the bone remodelling process by regulating the pathway of the receptor activator of nuclear factor kappa-B (RANK), the RANK-ligand (RANKL) and osteoprotegerin (OPG). (Figure 3) RANKL is expressed on preosteoblastic cells and binds to RANK on osteoclastic precursor cells, and by inducing osteoclast recruitment promotes bone remodelling. (Martin & Sims, 2005) OPG regulates this pathway by blocking the RANKL and disrupting RANK signalling. (Udagawa et al., 2000) Relaxin has been shown to promote the differentiation of mononuclear hematopoietic precursor cells into monocyctic osteoclasts, whereas oestrogen inhibits this process by inducing OPG expression. (Faccioli et al., 2009) Relaxin has also been shown to be able to induce osteoclastogenesis from precursor cells by similar RANK-mediated expression, but independent of osteoblastic RANKL, showing relaxin to be a potent osteoclastic activator. (Ferlin et al., 2010)

Outside of pregnancy, the main direct mediators of bone metabolism in the body are the parathyroid hormone (PTH) and calcitonin. During pregnancy, PTH is replaced through negative feedback by parathyroid hormone-related protein (PTHrP) that is secreted from the placenta and breasts, which, in turn, induces bone resorption. (C. S. Kovacs, 2014) While PTHrP stimulates calcium transport through the placenta to the foetus, it also promotes bone resorption by inducing RANKL expression. (C. S. Kovacs et al., 1996) Increased bone resorption has been found in first trimester bone biopsies, and bone resorption markers, such as PTHrP and calcitonin, have been shown to increase during pregnancy. (C. S. Kovacs, 2011; C. S. Kovacs & Kronenberg, 1997; Purdie et al., 1988) Increased levels of PTHrP during pregnancy are suppressed with increased OPG activity through increased oestrogen secretion. (C. S. Kovacs, 2014) In 2012, Møller et al. studied the bone mineral density of 153 women before, during and after pregnancy and found reversible bone loss during pregnancy of 3.2%, 2.4% and 4.2% in the lumbar spine, the hip and the whole body, respectively,
normalising at 19 months postpartum irrespective of the breastfeeding length. To & Wong published similar results in 2011 when they showed a reversible loss of bone mineral density by ultrasonography in the calcaneus during pregnancy, mostly recovering at 24 months postpartum.

After delivery and placental detachment, maternal levels of PTHrP fall drastically if breastfeeding is not started within hours. (Ardawi et al., 1997) Lactation also suppresses oestrogen and progesterone secretion by downregulating OPG expression. Both PTHrP secretion and OPG downregulation induce the RANKL-mediated pathway of osteoclastogenesis, increasing bone resorption. (C. S. Kovacs & Kronenberg, 1997) Calcitonin is produced by the breast tissue maternally to regulate the calcium content of milk secretion. (Woodrow et al., 2006) Over the lactation period of 3 to 6 months, a 5% to 10% loss of trabecular bone mineral density has been observed with somewhat smaller cortical losses. (C. S. Kovacs & Kronenberg, 1997; Sowers, 1996) For lactating adolescents, these figures seem to be higher. Indeed, in 1982, Chan et al. reported density losses of between 10% and 15%. Lactation volume correlates with bone mineral density loss. Accordingly, in 1998, Laskey et al. demonstrated higher bone loss when lactating twins.

Studies of bone mineral density have shown the bony skeleton of the parturient usually normalises between 6 and 18 months after cessation of lactation. (C. S. Kovacs, 2011; C. S. Kovacs & Kronenberg, 1997; Møller et al., 2012) Ultimately, parity and lactation do not increase the lifetime risk of osteoporosis or fractures. (C. S. Kovacs & Kronenberg, 1997; Sowers, 1996) In the FRAX-tool developed by the World Health Organisation (WHO) for assessing risk of fracture, parity and lactation are not listed as risk factors. (Trémollières et al., 2010) Despite transient loss of bone mineral density during pregnancy and lactation, parity and lactation have been shown to ultimately increase female bone strength and decrease lifetime fracture risk. (Specker & Binkley, 2005; Wiklund et al., 2012)
2.1.3 Orthopaedic disorders of pregnancy

2.1.3.1 Lumbar and pelvic pain

According to the findings of studies by S.-M. Wang et al. in 2004 and F. M. Kovacs et al. in 2012, one of the most common orthopaedic complaints during pregnancy is lower back pain with an estimated prevalence of 50% to 70%. Risk factors for lower back pain during pregnancy include a sedentary lifestyle and previous lower back pain during pregnancy. (F. M. Kovacs et al., 2012) The curvature of the lumbar spine, but not the cervical spine, has been shown to increase during pregnancy up to the third trimester. (H. Yoo et al., 2015) In 1987, Betz et al. found women with scoliosis did not show curve progression during pregnancy. Changes in collagen metabolism together with increased strain on the lumbar ligaments have been speculated to predispose pregnant women to lumbar...
disc pathology, although reliable epidemiological reports are lacking. 
(O’Connell, 1960)
In 1996, Sanderson & Fraser found that women who had borne children
had a higher incidence of degenerative spondylolisthesis when compared to
nulliparous women (28% vs 17%).

The combination of the pelvic ligament, especially in the sacroiliac joints,
and the widening of the pubic symphysis can be the cause of increased
pelvic ring instability, leading to pregnancy-related pelvic girdle pain (PPGP).
Prevalence is estimated to be 25% for serious pain, 8% for serious disability
and 7% for persisting symptoms during the puerperal period. (Wu et al.,
2004) Symptoms include stabbing, shooting or burning pain in the sacral,
gluteal and perineal regions, although the precise localisation of the pain is
often difficult. (Kristiansson et al., 1996; Wu et al., 2004) Symptoms usually
peak between the 24th and 36th week of pregnancy. (Wu et al., 2004) Risk
factors for PPGP include strenuous work, previous lower back pain, lower
back pain during pregnancy and trauma. (H. B. Albert et al., 2006)
Management is non-operative and the symptoms of 93% of patients resolve
within 3 months postpartum with only 1% to 2% reporting persistent
symptoms. (Kanakaris et al., 2011)

2.1.3.2 Peripheral neuropathies

Generalised oedema, in addition to the hormones relaxin and prolactin, has
been hypothesised to contribute to the development of peripheral
neuropathies during pregnancy. (Heckman & Sassard, 1994; C. A. Johnson,
1991; Schned, 1986) The most common of these are carpal tunnel
syndrome and de Quervain’s disease. While carpal tunnel syndrome usually
onsets during the late second or third trimester, de Quervain’s disease is
most common in the months following delivery. (Klein, 2013; Schned, 1986)
Treatment options for both syndromes include splinting and corticosteroid
injections, and symptoms usually resolve after delivery and the cessation of
lactation. Operative treatment is also available for highly symptomatic
cases. (Heckman & Sassard, 1994; C. A. Johnson, 1991; Nygaard et al., 1989;
Schned, 1986) Although several reports on the prevalence of carpal tunnel
syndrome during pregnancy have been published, to the best of our
knowledge, no reports on the epidemiology of surgical treatment exist.
(Bahrami et al., 2005; Khosrawi & Maghrouri, 2012; L. Padua et al., 2001; Stolp-Smith et al., 1998)

2.1.3.3 Fragility fractures

Pathologic idiopathic osteoporosis during pregnancy was first reported by Albright & Reifenstein in 1948. However, osteoporotic fractures have been found in the mummies of fertile-aged females from Ancient Egypt. (Stride et al., 2013) While pregnancy-associated loss of bone mineral density is a normal physiological phenomenon, some parturients experience excessive bone mineral density loss causing an osteoporotic state of the skeleton. We are unaware of the existence of any epidemiological data on this phenomenon, as only case reports and reviews have been published in the current literature. However, the literature does discuss several entities such as transient osteoporosis of pregnancy (TOP), pregnancy and lactation induced osteoporosis (PLO) and pregnancy-associated osteoporosis (PAO). (Hardcastle et al., 2019; Maliha et al., 2012; Qian et al., 2021) The pathophysiology in any of these reported phenomena is not currently known and they present with similar clinical phenotypes. At present, the suggested underlying pathology in the published literature is suggested to be a disturbance in normal PTHrP and OPG mediated calcium regulation. The current treatment for all the reported phenomena is also similar, and hence they are grouped and discussed below under the same entity TOP.

Most reports regarding transient osteoporosis during pregnancy and lactation describe the condition as a third trimester to post-delivery complication in an otherwise uneventful pregnancy. (Hardcastle et al., 2019; Maliha et al., 2012) Most studies concerning TOP report a clinical picture of the sudden onset of pain in the hip or lumbar area, which is aggravated by weight bearing and relieved with rest. (Emami et al., 2012; Hadjii et al., 2017; Hardcastle et al., 2019; Maliha et al., 2012; Willis-Owen et al., 2008; Wood, Larson, et al., 2003) TOP has also been described in the knees and talus. (Charpidou et al., 2013; Daniel et al., 2009) Initial radiology and bloodwork is usually negative, with radiography revealing calcium depletion and bone density showing clinical osteoporosis only a few weeks after initial clinical symptoms. (Beaulieu et al., 1976; Carbone et al., 1995; Ma & Falkenberg, 2006) Hip pain is usually unilateral, but bilateral pain has also been described. (Maliha et al., 2012) Magnetic resonance imaging
(MRI) can be used to distinguish TOP from avascular necrosis in its primary phase. (Gueria & Steinberg, 1995) Non-operative treatment with bedrest is usually preferred, and symptoms usually subside after delivery. (Maliha et al., 2012) Even displaced fractures have been described as underlying causes of acute hip pain with diagnosis delayed due to radiological concerns over the foetus. (Willis-Owen et al., 2008) Treatment with internal fixation for both hip fractures and severe post-facture lumbar kyphosis have been described, but delayed until after delivery. (Emami et al., 2012; Tanriover et al., 2009; Wood, Larson, et al., 2003)

2.1.4 Pregnancy and delivery

2.1.4.1 Pregnancy and delivery in Finland

In the year 2021, there were 49,069 deliveries and 49,726 live births in Finland. Perinatal mortality (including foetal deaths prior to delivery, deaths during delivery and neonatal deaths up to 28 days of age) was 3 per 1000 births. Moreover, there are 23 delivery hospitals in Finland with a median of 1,577 deliveries per hospital. In total, 35.4% of children were born in hospitals situated in the metropolitan area of Helsinki. In Finland, 99.3% of all childbirths occur in a hospital setting. (Finnish Institute for Health and Welfare, 2021)

The mean age of all women at the time of delivery was 31.6 years, which has risen during the past decade. The mean age of primipara women was 30.0 years. Mean BMI before pregnancy was 25.7 and 45.3% of women were overweight (BMI > 25). In Finland, the incidence of obesity in pregnant women has increased greatly in the past ten years. (Kuitunen et al., 2022) In 2021, 7.9% of women smoked during the first trimester with 56.4% subsequently stopping during the same period. This rate has increased dramatically since 2011 when 39.2% of smokers stopped smoking in the first trimester. (Finnish Institute for Health and Welfare, 2021)

The proportion of caesarean sections increased slightly in 2021, rising to 19.6% from long-time averages of 16% to 17%. Of all caesarean sections, 4.3% were emergency sections and less than 1% of all deliveries were emergency sections. For vaginal deliveries, 52.5% of women received epidural analgesia. (Finnish Institute for Health and Welfare, 2021)
2.1.4.2 Pregnancy and delivery after trauma

While a peripheral trauma acquired before or even during pregnancy is not thought to be a serious problem for a normal pregnancy, several studies have discussed the progression of normal pregnancy and the incidence of caesarean section as a delivery method for women with a history of pelvic and femoral trauma. (Cannada & Barr, 2010; Copeland et al., 1997; Fallat et al., 1998; Goswami et al., 2012; LV et al., 1983; Speer & Peltier, 1972; Tsvieli et al., 2012; Vallier, Cureton, & Schubeck, 2012) In his 2014 review, Riehl concluded that in the current literature 53% of women underwent caesarean section after previous pelvic fracture and 47% delivered vaginally. The most common indication was a history of prior caesarean section. In 2012, Vallier, Cureton, Schubeck, et al. reported that 43% of operatively treated pelvic fractures underwent successful vaginal delivery with 4 patients having retained hardware. In their recent nationwide cohort study from the Finnish population, Vaajala et al. reported the rate of caesarean section after previous pelvic fracture to be 23% in 2022. Pregnancies were otherwise uneventful.

Trauma has previously been evaluated to complicate one in twelve pregnancies. However, to the best of our knowledge, no epidemiological studies have been published regarding the course and outcomes of pregnancy with a concomitant trauma. (Murphy & Quinlan, 2014) In 2001, Weiss et al. conducted a 3-year retrospective cohort study in the USA where the incidence of foetal death due to maternal trauma during pregnancy was defined to be 2.3 per 100 000 live births. Possible foetal complications include preterm membrane rupture, preterm birth, uterine rupture, placental abruption, caesarean section and stillbirth. (El-Kady et al., 2004; Schiff et al., 2002; Schiff & Holt, 2005) Placental abruption has been estimated to be the cause of death in between 40% and 60% of traumatic foetal deaths. The rate of fetomaternal transfusion after trauma has also been evaluated to be up to 30% (Pearlman et al., 1990) Even if the foetus survives trauma, there is still a higher risk for low birth weight, premature delivery and permanent neurocognitive pathology. (El-Kady et al., 2004) In a recent study, maternal injury during pregnancy was associated with a
higher risk of child cerebral palsy (HR 1.3), with an even higher risk for those cases in which delivery was within 7 days of trauma. (Ahmed et al., 2023)

In addition to foetal complications, trauma during pregnancy has also been shown to be the leading non-obstetrical cause of maternal death with the highest risk being in the late second to third trimester. (Fildes J, Reed L, Jones N, Martin M, 1992; MC & MD, 2008; TJ et al., 1991) In a study by Kuo et al. from 2007, one third of parturients admitted due to trauma gave birth during the same hospitalisation period.
2.2 Epidemiology of fractures

Fracture epidemiology in adults of the whole population has been studied comprehensively. The most comprehensive report regarding fracture epidemiology in all adults in a whole-population setting was published by Court-Brown & Caesar in 2006. Their study in 2000 was a retrospective cohort study of a population of five hundred thousand in Scotland, and roughly 6000 fractures were collected. In their study, the overall fracture incidence of the adult population aged 12 years and older was 1170 per 100 000 person-years in males and 1065 per 100 000 person-years in females. Incidence curves in men and women showed different trends where the fracture incidence of men was a parabular bimodal shape with high peaks in early adulthood and old age. For women, only a small rise in incidence was seen in young adults with an even more extreme rise in older individuals after menopause. Previous studies have demonstrated that most fractures in the older population are osteoporotic fractures, whereas incidence peaks in the young are caused by high-energy trauma and increased risk-taking behaviour. (Denisiuk & Afsari, 2022; Farr et al., 2017; Lupsa & Insogna, 2015) Regarding fracture incidence in the whole population, similar results were published by Bergh et al. in 2020. Their retrospective 3-year cohort study of a population of five hundred thousand in Sweden yielded 27 000 fractures for a total fracture incidence of 1229 per 100 000 person-years. For men, the incidence was 1042 per 100 000 person-years and 1412 per 100 000 person-years for women. Moreover, the average age for male fractures was 48.7 years and 63.6 years for female fractures. For females, the most common fracture locations reported in both studies were the distal radius, the proximal femur, the ankle and the proximal humerus. (Bergh et al., 2020; Court-Brown & Caesar, 2006) Most of these fracture types are traditionally attributed as typical osteoporotic fractures and their incidence is expected to rise as the general population ages. (Kannus et al., 2001) In 1997, Johansen et al. published slightly higher results, reporting a whole-population fracture incidence for females of 1880 per 100 000 person-years. In their study, over half of the fractures were fractures of the small bones in the hand and foot, and differences in incidence figures are likely attributable to differences in cohort formation and national patient care settings.
2.2.1 Fracture epidemiology in fertile-aged females

The WHO defines the fertile age of a female as being between 15 and 49 years. (World Health Organisation, 2006) When analysing the incidence rates of pregnant women, the most accurate comparison rates can be drawn from a normal population of similar aged females. To date, the most comprehensive figures were published by Farr et al. in 2017. In their study, they described the fracture epidemiology of all 18 to 49-year-olds in a population of 2500 people over a 3-year period in a county in the USA. The total fracture incidence for females was 1007 unique fracture patients per 100 000 person-years and 1513 unique fractures per 100 000 person-years for males. Male to female ratio was 1.6:1, which is higher than in the whole US population. (Bergh et al., 2020; Court-Brown & Caesar, 2006; Farr et al., 2017) Johansen et al. reported similar values in 1997 for the female population aged 25 to 54 years. However, both markedly higher and lower values ranging from 150% to 67% have also been reported, most likely explained by differing data gathering and cohort collection methods. (Donaldson et al., 1990; van Staa et al., 2001)

In the 2017 study by Farr et al. of different age groups of women aged between 18 and 49 years, total fracture incidence was lowest in women aged 18 to 24 years and highest in women aged 45 to 49 years with incidence rising steadily with age. This phenomenon was mostly due to a large increase in fractures of the ribs and ankle. Other fractures were relatively stable with age except for fractures of the skull and face, which had the highest incidences in the youngest population aged 18 to 24 years. High energy trauma was the leading cause in 71% of all fractures. The most common mechanisms were occupational (30%) and recreational (18%), falls from height (14%) and motor vehicle accidents (10%). Of all the fractures sustained by females aged 18 to 49 years, 22% were caused by falls from standing height, with a 1:2 male to female ratio. Fractures of the foot and hands accounted for 40% of all fractures. After these, the most common fractures were ankle fractures (12%), distal forearm fractures (8%), facial/skull fractures (7%) and thoracolumbar vertebral spine fractures (5%). Interestingly, these findings present a clear difference in profile from those fractures of the general female population which is attributable to the absence of osteoporotic fragility fractures. (Bergh et al., 2020; Court-Brown & Caesar, 2006; Farr et al., 2017) Female sex, a lack of physical activity,
high-demand labour, smoking, both no and high alcohol consumption and living alone have all been associated as risk factors for fractures in the middle-aged population. (Cecilia Rogmark et al., 2021)

To the best of our knowledge, no epidemiological studies regarding fracture incidence rates in the total pregnant or postpartum female population have been published yet.

2.2.2 Common fractures in young adults

2.2.2.1 Ankle fractures

The most common fractures in the young female population, ankle fractures, account for as much as 10% of all bone injuries, even in the general population. (Court-Brown & Caesar, 2006) In 2017, Farr et al. reported the incidence in the female population aged 18 to 49 years to be 136 per 100 000 person-years. However, in their study from 2018, Elsoe et al. reported an incidence of 100 fractures per 100 000 person-years from a single level 1 trauma centre in females aged 20 to 39 years in the Danish population. In 2018, Juto et al. reported similar incidences for women of the same age of 80 to 90 per 100 000 person-years in the Swedish population. In the United Kingdom, Scott et al. reported the incidence of hospitalised ankle fractures for the population aged 16 to 39 years in 2020 to be 27 per 100 000 person-years. Here, the lower rates are possibly explained by the cohort only comprising hospitalised cases. While high-energy trauma is the most common cause of fracture for young adult females, ankle fractures are most often caused by low energy trauma, such as falling from standing height. (Juto et al., 2018) According to Scheer et al., from 2020, while falls account for 50% of ankle fractures, 37% occur in sports or other exercise activities, which probably describes the injury mechanism trends of the younger population.

Previously, more than half of ankle fractures have been found to be trans-syndesmotic type B fractures, according to the Danis-Weber classification. (Juto et al., 2018; B. G. Weber, 1966) The portion of bi- and trimalleolar fractures has previously been defined to be 40% to 56%. (Juto et al., 2018; Thur et al., 2012; Vankarr et al., 2022) In a study by Thur et al. from 2012, the operation rate for ankle fractures in the whole female
population was 81%. In their 2020 study, Scott et al. reported that 85% of patients with an hospitalised ankle fracture were treated operatively in the population aged 16 to 39 years. The most common method of fixation was internal extramedullary fixation (60%) followed by intramedullary fixation (17%). Surgical rates and the proportion of internal fixation between 2007 and 2017 remained stable in the female population.

2.2.2.2 Distal radius fractures

Fractures of the distal forearm include fractures of the radius and ulna, starting from the distal metaphysis which surrounds the distal radioulnar joint. Although combined fractures of the radius and ulna are often seen, isolated fractures of the distal radius and the ulna are also possible. Fractures of the distal radius are the most common, with isolated ulnar fractures accounting for only 2% of all distal forearm fractures. (Soerensen et al., 2022) The epidemiology of distal radius fractures has been studied extensively. In their literature review from 2016, MacIntyre & Dewan gathered 22 publications from 5 continents that described variations in incidence rate as high as 60%, depending on the diagnostics and cohort formation methods used. In a multicentre retrospective cohort study from a single geographical area in Finland, the incidence rate of distal radius fractures was 107 per 100 000 person-years in females aged 16 to 29 years. Respective nationwide figures from a retrospective cohort study in Sweden yielded an annual incidence of 60 per 100 000 person-years in females aged 18 to 49 years. (Mellstrand-Navarro et al., 2014) In that study, the mean age of fracture in the whole population for females was 53 years. Epidemiologically, females show a strong incidence peak at the age of 5 to 15 years, after which incidence rates fall dramatically up to the onset of menopause. In a retrospective cohort analysis for the years 1999-2010 from Sweden, Jerrhag et al. reported that the number of yearly distal radius fractures had risen by 30% and projected a further 20% increase by the year 2050. Moreover, the authors of the study reported that the largest increase in incidence in the whole female population was seen in females aged 40 to 59 years.

In their study, Flinkkilä et al. reported that 62% of distal radius fractures were metaphyseal extra-articular fractures (type A according to the
AO/OTA-classification) of the distal radius, (Marsh et al., 2007), and a further 79% were classified as a typical Colles’ fracture. (Colles, 1814). The lowest mean age was seen with type B fractures at 49 years, with these fractures being most commonly the result of a high energy mechanism (35%). In the whole population, the most common injury mechanism was a fall from standing height (77%) followed by bicycle accidents (5%) and high falls (4%). (Flinkkilä et al., 2011) From previous reports, it can be understood that around 80% of all distal radius fractures can be treated non-operatively, with closed reduction and casting being the preferred option. (Azad et al., 2019; Mellstrand-Navarro et al., 2014) While historically external and percutaneous fixation were the most common methods, the development of locking plates has seen a significant rise in the share of internal fixation in operative treatment, mostly replacing external fixation. (Azad et al., 2019; Mattila et al., 2011; Mellstrand-Navarro et al., 2014) For young patients aged 20 to 39 years, 72% of fractures were treated non-operatively with 24% requiring internal fixation. (Azad et al., 2019) From a nationwide register study in Finland, the incidence of internal fixation with plating in females aged 40 to 59 years in 2008 was 44 per 100 000 person-years. The complication rate of surgery has previously been established to be 9%, with non-operative treatment carrying a 5% risk of complication. The most common complications associated with operative treatment are mechanical symptoms and infections. (Azad et al., 2019)
2.3 Lumbar, pelvic and femoral fractures in young females

Lumbar vertebral fractures are one of the most common fractures in young adults. (Farr et al., 2017) The treatment of these fractures is often non-operative, but pain can be immobilising. However, operative treatment is sometimes required, especially with fractures caused by high-energy trauma. It is in these types of cases that lumbar spine fractures are occasionally accompanied by pelvic trauma. While the outcomes of lumbar spine fractures remain good, pelvic trauma often leads to poor outcomes. (Madhu et al., 2007)

In a normal pregnancy, the foetus lies in the abdomen surrounded and protected by the pelvic and lumbar bones. The lumbar spine, the sacrum, the coccyx, the ilium, the ischium and the pubis form the pelvic ring which connects the femur to the vertebral column. This ensemble not only supports our upper body and enables us to walk, but also provides a safe supporting platform for all the enclosed soft tissue. For the first 12 weeks of pregnancy, the foetus lies within the small pelvis, protected by bony anatomy. Thus, foetal trauma requires direct bony trauma of the pelvis. Pelvic fractures are critical, especially during pregnancy, and are associated with increased mortality for both the mother and the foetus. (Leggon et al., 2002)

In contrast, femoral fractures often present symptoms of extreme immobility and pain. They are also reported with high incidences of foetal complications, possibly due to their common high-energy nature in the young. In addition, femoral fractures often require surgery, which in itself poses a challenge for young patients, which is further complicated by pregnancy. (Harold et al., 2019)
2.3.1 Epidemiology

2.3.1.1 Lumbar spine fractures

Spine fractures in the general population are a relatively rare entity with a pooled incidence of 7.5 per 100 000 person-years. Indeed, they are reported to be responsible for only 0.7% of all fractures in the adult population. (Court-Brown & Caesar, 2006; Ponkilainen et al., 2022) While whole-population data have been published, data regarding the young female population are scarce. In one of the most recent studies on the subject published in 2020, Ponkilainen et al. reported the incidence of hospitalised lumbar spine fractures in their nationwide cohort study was 52 per 100 000 person-years for the whole Finnish population in 2017, with lumbar fractures accounting for 60% of all spine fractures. In their 2022 study, Wakim et al. found the whole-population incidence of lumbar fractures in the USA in 2018 to be 23 per 100 000 person-years. In that study, females sustained 60% of all lumbar fractures with an incidence of 14 per 100 000 person-years. The mean age for all patients with lumbar fracture was 67 years. The main mechanism of injury in the whole population appeared to be different types of falls, with falls from stairs, ladders, the bed or standing height accounting for 63% of all fractures. After these, sports accounted for 9% of fractures. The most common location of fracture seems to be in the thoracolumbar junction, with incidences decreasing when moving up or down the spine. (Van der Klift et al., 2002) The prevalence of lumbar fractures in the whole population rises with increasing age with the highest prevalence seen in patients older than 90 years. (Melton et al., 1989)

The incidence of lumbar spine fracture surgery has previously been reported to be 2.4 per 100 000 person-years. However, the rate of surgery has also declined during the past decade. This suggests that the majority of lumbar spine fractures are now treated non-operatively. (Ponkilainen et al., 2020)

To date, no large-scale epidemiological studies of lumbar spine fractures during pregnancy have been published. One single centre study of osteoporotic low-energy compression fractures during pregnancy was published by Yildiz et al. in 2021. In their retrospective study of MRI scans for varying indications in pregnant or postpartum women, 12% of scans
were positive for vertebral fracture. The prevalence of osteoporotic fractures was 0.47%, where all but one patient had multiple fractures. We are unaware of further epidemiological data regarding lumbar spine fractures in pregnant or postpartum women.

### 2.3.1.2 Pelvic fractures

Pelvic fractures have been estimated to represent 1.5% of all adult fractures in the whole population with an estimated pooled incidence of 33 per 100 000 person-years. (Court-Brown & Caesar, 2006; Ponkilainen et al., 2022) Overall, the profile of patients with pelvic fractures is similar to that of patients with lumbar spine fractures, but pelvic fractures seem to be more frequently associated with high energy mechanisms. In a nationwide register-based cohort study by Rinne et al. from 2020, the incidence of hospitalised pelvic fractures rose from 34 per 100 000 person-years in 1997 to 56 per 100 000 person-years in 2014. The sex-specific incidence for women aged 18 to 64 years in 2014 was 20 per 100 000 person-years. Similar nationwide results from Sweden were published in 2021. (Lundin et al., 2021) A limitation of these studies is that they do not include those patients who died before reaching hospital. Overall, 65% of fractures occurred in women, with women older than 64 years being the largest demographic group. (Rinne et al., 2020) In 2007, Balogh et al. published figures from a level 1 trauma centre in Australia. They reported a whole population incidence of 23 per 100 000 person-years. While age- and sex-specific incidence rates were not reported, approximately 35% of all fractures occurred in patients aged between 10 and 50 years. Pelvic fractures in this age-group were split with half being high-energy trauma patients who survived to reach hospital and the other half dying before they reached hospital. Only single cases of low energy trauma were reported, which yields a high overall mortality. In this age group, 40% of patients were female and the median age was 41 years. According to previous reports, injury mechanisms in pelvic fractures are dominated by motor vehicle accidents, including car crashes, motorcycle accidents and pedestrians being hit by motorized vehicles. These injuries are estimated to account for up to 45% of all pelvic fractures and 80% to 85% of all high-energy pelvic fractures. Low-energy trauma accounts for another 45% of
pelvic fractures, with fractures almost exclusively caused by falls from standing height. (Balogh et al., 2007; Demetriades et al., 2002) In 16% of cases, pelvic fractures are associated with associated visceral injuries with trauma of the liver (6%), bladder and the urethra (6%) and the spleen (5%) being the most common. (Demetriades et al., 2002)

In the whole population, the incidence of operative treatment of all pelvic fractures was 8% in 2014 (4.3 per 100 000 person-years). The respective incidence in females aged 18 to 64 years was 1.0 per 100 000 person-years. (Rinne et al., 2020) In the 2007 study of high-energy mechanism patients by Balogh et al., 10% of predominantly young patients underwent emergency angiography, 12% emergency laparotomy and 15% emergency pelvic ring fixation with either internal or external fixation within 12 hours of admission.

While studies have been published on the epidemiology of pelvic ring fracture in the young female population, no epidemiologic data regarding pelvic ring fractures in the pregnant or postpartum population have been published to date. The only current published literature are a series of case reports and literature reviews. (Leggon et al., 2002; Zhang et al., 2012) Pelvic fracture during pregnancy has been associated with a 9% maternal death rate (possibly lower than in the non-pregnant population) and a 35% foetal death rate of which 73% are caused by motor vehicle collisions. Although reports on surgery of the pelvic ring and acetabular fractures do exist, both are rare. (Dunlop et al., 1997; Pals et al., 1992; Pape et al., 2000; Yosipovitch et al., 1992)

2.3.1.3 Femoral fractures

Femoral fractures are one of the most common fractures in the general population. Most of these fractures are proximal femoral fractures which account for 12% of all adult fractures with a pooled incidence of 113 per 100 000 person-years. However, femoral shaft fractures are much rarer, only accounting for 0.9% of all fractures with a pooled incidence of 12 per 100 000 person-years. (Court-Brown & Caesar, 2006; Ponkilainen et al., 2022) In a nationwide Swedish cohort published in 2021 by Lundin et al., the incidence of femoral fractures of women aged 18 to 49 years was established to be 5.8 for proximal femoral fractures and 2.6 for femoral...
shaft fractures. In the same study, one-year mortality after proximal femoral fracture was 3.5% and 2.2% after femoral shaft fracture.

In cases of proximal femoral fractures in young females, the fractures are almost exclusively fractures of the femoral neck. (Bäcker et al., 2021) In 2015, Stockton et al. reported that 33% of femoral fractures in the population younger than 60 years are the result of a high energy mechanism. The respective rates in the fertile-aged population are possibly even higher due to a large increase in the incidence of low-energy trauma in patients older than 50 years. (Bäcker et al., 2021) Similar trends have been reported for femoral shaft fractures in patients aged 11 to 40 years who sustain fractures almost exclusively due to high energy mechanisms. However, by the age of 50 to 60 years, the predominant trauma mechanism shifts almost entirely to low energy mechanisms. (Enninghorst et al., 2013; R. J. Weiss et al., 2009)

Both proximal femoral fractures and femoral shaft fractures in the young are almost always treated operatively with most operations being almost exclusively due to other life-threatening injuries. However, no epidemiological data have been published on the incidence of operative treatment. Complication rates are high both due to the effects of concomitant trauma in high energy fractures and the poor functional outcomes after operative fixation, especially in femoral neck fractures. (Bäcker et al., 2021; Dedrick et al., 1986; Enninghorst et al., 2013; Stockton et al., 2015; R. J. Weiss et al., 2009)

Regarding the epidemiology of proximal femoral and femoral shaft fractures in pregnant or postpartum women, no large-scale epidemiological studies have been published. The largest case series on femoral shaft fractures during pregnancy is from 2008 and involved 8 patients. (Porter et al., 2008) For femoral neck fractures, most case reports describe fractures associated with transient osteoporosis. While the prevalence of TOP is evaluated at 1 per 250 000 pregnancies, reports on fracture complications are limited to single case reports. (Factor et al., 2022; Harold et al., 2019)
2.3.2 Diagnostics and classification

2.3.2.1 Lumbar spine fractures

The diagnostics of lumbar injuries have evolved greatly over the past centuries. While paraplegia, as a symptom, has been described for over 2000 years, the diagnostics remained clinical with neurological examination and palpation of the spine. However, it was the development of X-rays and later computerised tomography (CT) that finally revolutionized spine fracture diagnostics. (Silver, 2005)

The first classification system to describe lumbar fractures was developed by Holdsworth in 1964, but it was not until 1994 that Magerl et al. developed the first widely used classification system using traditional AO-principles known as the AO-Magerl classification. This was the primary classification system in use until 2005 when the Spine Trauma Study Group developed the Thoracolumbar Injury Classification and Severity Score (TLICS) which also considers the neurological state of the patient to further help guide treatment. However, the TLICS was criticised for overemphasising the importance of the posterior ligamentous complex. In response to these criticisms, the AO Spine group published a revised classification for thoracolumbar injuries in 2015. (Vaccaro et al., 2013) The AOSpine TL classification divides thoracolumbar fractures into type A (compression fracture), type B (failure of anterior or posterior tension band of the spine) and type C (severe displacement) with better interobserver reliability than the TLICS score. (Kaul et al., 2017) Although both systems are still in use today, vertebral burst-fractures provide a special challenge, as neither system is fully equipped to assess fracture characteristics regarding treatment indications. (Azhari et al., 2016; Hitchon et al., 2016; Andrei Fernandes Joaquim et al., 2016)

2.3.2.2 Pelvic fractures

The first modern mention of pelvic fractures comes from the works of Joseph-François Malgaigne who published the first written mention of the modern vertical shear pelvic fracture, later eponymised as Malgaigne’s fracture in 1847. (Stahel & Hammerberg, 2016) Initial diagnostics were
clinical with methods such as palpating the bony anatomy of the pelvis and inspecting limb shortening, and mortality was high. The introduction of the anteroposterior (AP) view X-ray enabled a more specific classification of pelvic fractures. The first to establish a fracture pattern classification based on anatomic location was Watson-Jones in 1938. While several attempts were made to further improve the classification over the following years, it was not until 1980 that Pennal et al. published the first pelvic fracture classification which divided fractures by fracture mechanism into anteroposterior compression (APC), lateral compression (LC) and vertical shear (VS). In 1986, Young et al. further refined this classification by dividing fracture types based on their stability and ligamentous injuries to create the Young-Burgess classification which is still in use today.

2.3.2.3 Femoral fractures

While the diagnostic development of the most common femoral fracture in young females, the femoral neck fracture, began in 1823 with Sir Astley Cooper developing the division of proximal femoral fractures into intra- and extracapsular fractures, it was not until 1935 that the first biomechanical classification, the Pauwels classification, was presented. (Bartoníček, 2001) In the original Pauwels classification, the angle of the fracture line, proportional to the amount of shearing force, is used to divide fractures into three types. In 1961, Robert Garden published his own classification which further evaluated the relationship of the fracture to femoral trabeculae and is still in use today. In Garden’s classification, femoral neck fractures are divided into four categories based on AP X-rays. Type I fractures are incomplete, non-displaced valgus impacted fractures where the lateral cortex is interrupted, but the medial cortex remains intact. Type II fractures are complete, non-displaced fractures of the femoral neck. Type III fractures are complete fractures with slight displacement where trabeculae are angled. Type IV fractures are displaced, complete fractures where trabeculae are parallel around the fracture line. (Garden, 1961)

For femoral shaft fractures, the most common fracture classification system is the AO/OTA system. (Marsh et al., 2007) This classification divides femoral shaft fractures into 3 categories based on their pattern. Type A fractures are simple fractures, further divided into spiral (A1), oblique (A2)
and transverse fractures (A3). Type B fractures are wedge fractures with B1 indicating a spiral, B2 a bending and B3 a comminuted fracture. Type C fractures are complex fractures of either a spiral (C1), a segmented (C2) or an irregular pattern (C3). (Marsh et al., 2007)

2.3.3 Treatment

2.3.3.1 Lumbar fractures

The treatment of lumbar fractures revolves around the ability of the fractured spine to maintain its lordosis and height, and to protect the patient against possible neurologic deficits. This assessment relies heavily on both the radiologic recognition of correct fracture patterns and the neurologic condition of the patient and can be simplified into the division of fractures into stable and unstable fractures. This categorisation leads to a further simplification between non-operative for stable fractures and operative treatment for unstable fractures. (Andrei F Joaquim et al., 2019; Vaccaro et al., 2005, 2013)

Although the first definition of vertebral instability was provided by White & Panjabi in 1978, there is still uncertainty regarding the absolute definition of an unstable spine. While the new classifications, TLICS and AOSpine, were developed to provide help with clinical decision making, and clinical consensus regarding operative treatment in patients with TLICS over 5 points remains unchallenged, these classifications still leave many patients in the intermediate category where decision making is left to the clinician. (Kaul et al., 2017; Vaccaro et al., 2005, 2006) Further, whereas Nataraj et al. in their 2018 cohort study were unable to show a difference between operated and non-operated TLICS 4 patients, in 2020, Karaali et al. found operated patients in a similar setting had lower scores of kyphotic angles, vertebral height loss and faster return to work. In 2016, Hitchon et al. reported from their retrospective cohort study that up to one quarter of non-operatively treated TLICS 2 burst fractures would require delayed surgery due to mobilisation-limiting pain.

While historically the operative treatment of lumbar fractures consisted of a laminectomy, with the intention of decompressing the spinal cord, and traction, progress made in the design of surgical instruments and implants
in the 1980s progressed lumbar fracture treatment. The initial method of vertebral fixation was laminar wiring, and Harrington rods were the first implementation of rigid bars to support the spinal column. (Gertzbein et al., 1982) However, unsatisfactory results led to the development of transpedicular screw fixation using short-segment bars. (Krag et al., 1986) Soon after, fusion was added to the procedure, yielding the technique that is still in use today. (Dickman et al., 1992) In type B burst fractures, however, fusion in short-segment pedicle screw stabilisation has not been shown to lead to better outcomes when compared to non-fusion. (Dai et al., 2009) One randomised trial has shown that intermediate screws to the fracture level possibly aid with fusion and stability while three-level and two-level fixation seem to lead to similar outcomes. (K. Li et al., 2016; Park et al., 2016) Modern percutaneous techniques have been developed with one randomised trial showing no clear benefit over open procedures. (Lyu et al., 2016) Although unstable fractures should be considered candidates for early operative treatment, complete neurologic injury can be considered a relative indication. (Azhari et al., 2016; Andrei F Joaquim et al., 2019) For non-operative treatment, an extension brace has traditionally been used. However, in a recent randomised trial, the extension brace was shown to add no benefit in type A compression fractures and should, therefore, be reserved for type B injuries. (Urquhart et al., 2017) When patients are correctly chosen for non-operative treatment and observed, they recover with good outcomes and operative treatment provides no additional benefit. (Shen et al., 2001; Shen & Shen, 1999)

2.3.3.2 Pelvic fractures

While the classification of pelvic fractures evolved during the first decades of the 20th century, the role of the orthopaedic surgeon in the treatment of pelvic trauma was minimal. At first, treatment focused mainly on concomitant visceral injuries, and bony injuries were most often treated non-operatively. (Peltier, 1976) However, after the first external fixation device was only introduced in 1975, internal fixation gained in popularity during the following decade. Initially, operative treatment was reserved for vertically unstable fractures, but was soon extended to rotationally unstable injuries as well. (Bosch et al., 1992; Goldstein et al., 1986; J M Matta & Saucedo, 1989; Släitis & Karaharju, 1975) As the Young-Burgess
classification system developed, the treatment of pelvic fractures has centred on classifying pelvic fractures into stable and unstable fractures based on their ligamentous damage. LC and APC type I fractures are considered stable and can usually be managed non-operatively, whereas other higher energy fracture types are associated with axial or rotational instability, higher mortality, higher blood loss and are thought to benefit from operative reconstruction. (T. Manson et al., 2010; J M Matta & Saucedo, 1989; Tile, 1988; Young et al., 1986) However, strong scientific evidence is lacking, and no published trials that compare the operative treatment of APC II-III or VS injuries to any other kind of treatment exist. Due to the high-energy mechanisms often associated with these types of unstable injuries, patients are often hemodynamically unstable and are associated with increased blood loss. A pelvic binder has been shown to be a good emergency tool for pelvic compression, especially in fractures with instability in external rotation. However, evidence regarding its effect in limiting blood loss is limited. (Schweigkofler et al., 2021, 2022) For unstable fractures, the guidelines recommend that pelvic reconstruction be performed within 72 hours of sustaining injury. (British Orthopaedic Association Audit Standards for Trauma, 2018; National Institute for Health and Care Excellence, 2016) Most fractures can be treated posteriorly with the most common fixation method being percutaneous iliosacral screw fixation. (K. Chen et al., 2019; Axel Gänsslen et al., 2006) For residual instability, anterior plating can be performed in the same setting. (Joel M. Matta, 1996) For extreme injuries with spinopelvic dissociation, spinopelvic fixation has been performed with good outcomes. (Patel et al., 2022) For patients that are hemodynamically unstable or are otherwise unsuitable for primary internal fixation, an external fixator can be used either as a temporary or definite treatment measure. (Haidukewych et al., 2003; Placzek et al., 2006) Despite the lack of comparative evidence, excellent outcomes after the operative treatment of rotationally unstable fractures have been published, and severe disability has been described to associate with the non-union of primarily unstable pelvic fractures. (Kanakaris et al., 2009; Tornetta et al., 1996; Van Loon et al., 2011) Although LC II injuries are traditionally treated operatively as unstable fractures, a recent cohort study managed to show no benefit for operative treatment regarding mobilisation time and pain. (J. Hagen et al., 2016) Similar results were achieved by Slobogean et al. in their randomised study in 2021, showing
that pain and functional outcome benefits were minor in LC I-II injuries when treated operatively. For stable pelvic fractures, non-operative treatment with weight bearing as tolerated has been shown to lead to acceptable functional outcomes with minimal fracture displacement. (Gaski et al., 2014; Sembler Soles et al., 2012) In combined injuries, the acetabulum can be treated separately after pelvic ring deformity correction with posterior fixation followed by anterior fixation with either internal fixation or arthroplasty with similar outcomes. (Borg et al., 2019; A Gänsslen et al., 1996; T. T. Manson et al., 2022)

2.3.3.3 Femoral fractures

Fractures of the femoral neck are under great stress due to their anatomy and subsequent physiological forces. Operative treatment is widely accepted as the treatment of choice with either arthroplasty or internal fixation, depending on the fracture type, with arthroplasty providing better outcomes, especially in the older population. (Blomfeldt et al., 2005; Chammout et al., 2012; C. Rogmark et al., 2002; Tidermark et al., 2003) Non-operative treatment has been almost exclusively reserved for low demand patients with Garden 1 non-displaced fractures. (Hardy et al., 2019) Due to higher physical demands in younger patients, however, femoral neck fractures are almost exclusively treated operatively. The fracture disturbs the blood flow of the femoral neck arteries and the rate of femoral neck aseptic osteonecrosis has been calculated to be 20% of patients post-operatively, with 18% requiring reoperation. (Stockton et al., 2019; Swiontkowski et al., 1984) Treatment options include fixation of the femoral neck with multiple compressive screws or a fixed angle implant with fixed angle implants that possibly provides better stability in higher shear fractures. (Bonnaire & Weber, 2002; Zhou et al., 2007) To date, no studies have compared internal fixation with arthroplasty in younger patients. Currently, arthroplasty is reserved for revision surgery with a total arthroplasty procedure. (Stockton et al., 2019)

For femoral shaft fractures, operative treatment is indicated for most patients, especially younger adults, with almost none treated non-operatively. The gold standard of treatment to date remains intramedullary nailing, which should be performed 24 to 48 hours after admission, as delayed operations increase the risk for pulmonary and systemic embolic
complications. (Bone et al., 1989; Charash et al., 1994; K. D. Johnson et al., 1985; Randelli et al., 2015) Developed in 1940 by Gerhard Küntscher, the primary method of femoral nailing was a trochanterically inserted antegrade nail which has since been joined by a piriformis entry technique with no obvious outcome benefit for either. (Sheth et al., 2016; Stannard et al., 2011) An alternative technique for antegrade nailing is the retrograde nail, again with no obvious benefit. (Daglar et al., 2009; Ostrum et al., 2000; Toluse et al., 2015; Tornetta III & Tiburzi, 2000) As high as 11% of high-energy fractures, predominantly in younger patients, have been shown to be open fractures. (Enninghorst et al., 2013) Associated compartment syndrome has also been shown to be prevalent in up to 48% of femoral shaft fractures. (Mithöfer et al., 2004) Especially in cases where wounds might have to be left open, an external fixator has been shown to be an effective treatment of choice, either as a temporary or definitive method of fixation. (Pairon et al., 2015; Testa et al., 2017)

2.3.3.4 Pregnancy-related factors for treatment indications

For the pregnant patient, indications for operative treatment in fractures of the lumbar spine, pelvis and femur during pregnancy remain the same as those in a non-pregnant patient, and failing to treat fractures accordingly could have devastating complications for the mother. (K. D. Johnson et al., 1985) Emergency room resuscitation is performed with standard protocol, but physicians should be aware of the risk of amniotic fluid embolism in the pregnant patient. (Pape et al., 2000) A pelvic binder can be used as normal in a pregnant patient, but in the case of extreme vena cava compression from the uterus, the mother should be log rolled into at least 15 degrees of left lateral tilt. (Cluver et al., 2013; Flik et al., 2006) One of the most important factors to consider is foetus viability. While foetuses are considered viable at 22 gestational weeks of age, foetuses delivered before 30 weeks of gestational age have shown an increased risk for cerebral palsy. (Kaempf et al., 2009) If the foetus is not viable and operative treatment is indicated immediately, the operation can proceed with standard protocol. If the foetus survives the initial traumatic insult and is deemed viable, a decision can be made to either proceed with delivery before surgery or make modifications to the surgical protocol, such as using external fixation as a definitive treatment method, or using traction do delay definitive
treatment until a safe caesarean section can be performed. (Amorosa et al., 2013; Leggon et al., 2002) According to the American College of Obstetricians and Gynecologists (ACOG) committee, regional anaesthesia should be preferred over general anaesthesia whenever possible. The use of foetal monitoring should be decided on in a multidisciplinary setting. (Van De Velde & De Buck, 2007) General anaesthesia carries an increased risk for spontaneous abortion during the first trimester and reduces foetal drug exposure overall. However, regional anaesthesia bears an increased risk of sudden hypotension, which is potentially harmful to the foetus. (Douglas & Choi, 2000)

To the best of our knowledge, no reports on lumbar fracture surgery during pregnancy have been published. We are aware of three case reports that describe surgery of 12th thoracic vertebral fracture both during pregnancy with standard protocol and delayed surgery with bed rest for several months before elective caesarean section in the same setting before spinal fracture surgery. (Lenarz et al., 2009; Sonawane et al., 2018; Tanchev et al., 2000)

The best level of evidence in fractures of the lumbopelvic area during pregnancy are reported in pelvic fractures. In 2011, Leggon et al. published a review of 101 cases of pelvic ring and acetabular fractures treated during pregnancy. Of these, 89% were pelvic fractures and 11% acetabular fractures. Maternal death rates were 9% and 8% and foetal death rates 36% and 25% respectively. In 52% of cases, foetal mortality was reported to be the result of direct injury and the result of maternal haemorrhage in 36%. At least 85% of fractures were the result of high energy trauma with 40% of fractures being of complex morphology. In total, 85% of acetabular fractures were treated operatively, but only 1 report mentioned external fixation and only 4 reports internal fixation of the pelvis. However, in context, most reports were published before 1970 in an era where modern orthopaedic fixation devices had not yet been developed.

For traumatic femoral fractures, the best reports are case reports from Harold et al. who in 2019 described three cases with one femoral neck and two femoral shaft fractures of gestational ages of 30, 24 and 31 weeks. The femoral neck fracture was atraumatic, whereas the shaft fractures were the result of high energy trauma. All fractures were treated operatively. One premature membrane rupture was diagnosed after operative treatment of a femoral shaft fracture due to motor vehicle collision and led to preterm
birth. Regarding osteoporotic femoral neck fractures during pregnancy, most reports of TOP-related fractures are reported to have been diagnosed after delivery, but those diagnosed during pregnancy are treated with the same principles as traumatic femoral neck fractures. (Factor et al., 2022; Willis-Owen et al., 2008)

2.3.4 Rupture of the pubic symphysis

The pubic symphysis is a cartilaginous joint holding the anterior ring and the pelvis together. Normally 3 mm to 6 mm wide in adults, it can stretch up to 1 mm to 2 mm when walking and can rotate up to 1°. (Stolarczyk et al., 2021) Supported by the superior, inferior, anterior and posterior pubic ligaments, the pubic symphysis loosens and widens during pregnancy to facilitate labour due to the effect of relaxin and the pressure of the uterus. A widening of 3 mm to 5 mm is normally observed during pregnancy which then returns to normal within 5 months of delivery. (Becker et al., 2010) While more commonly referred to during pregnancy as pubic symphysis dysfunction, which mostly settles after delivery, as a rare complication, the supporting ligaments can tear and the pubic symphysis rupture during vaginal delivery, causing potentially severe disability and complications. (Owens et al., 2002; Shnaekel et al., 2015)

The literature suggests the epidemiology of pubic symphysis rupture to be between 1 per 300 to 1 per 30 000, but no studies could be found that detail the latter figure. To the best of our knowledge, the only epidemiological report of symphysis pubis rupture after vaginal delivery comes from Yoo et al. who reported the incidence to be 1 per 385 in 2014. In their study, the mean age of patients was 31.5 years, and mean gestational age was 37.8 weeks. Primiparity and twin gestation were identified as risk factors for symphysis rupture.

The diagnosis of pubic symphysis rupture can be made clinically. Pain over the symphysis, positive Patrick’s test and a positive Trendelenburg sign have the highest sensitivity. Pain when walking or a swaying gait can also be observed. (H. Albert et al., 2000; Jain et al., 2006) Sometimes an audible snap can be heard and felt during delivery. (Palvia et al., 2017) Still, radiologic imaging with X-ray and MRI are the most specific ways to diagnose pubic symphysis rupture, with a widening over 10 mm in the AP-
view of the pelvic X-ray considered pathologic, and MRI giving the most accurate view of the supporting ligaments. (Herren et al., 2015; Wurdinger et al., 2002; J. J. Yoo et al., 2014) In 1996, Kurzel et al. proposed two cases where an MRI scan demonstrated an even larger symphysial gap than traditional X-ray. Early diagnosis is important, as the correct treatment can decelerate symptom progression. (Jain et al., 2006) Moreover, spinal or epidural analgesia during delivery can temporarily mask initial symptoms. (Snow & Neubert, 1997)

Treatment of pubic symphysis rupture is almost always initially non-operative and is limited to pain medications and accessories for ambulation. (Osterhoff et al., 2012; Palvia et al., 2017; J. J. Yoo et al., 2014) One case series has been published detailing the successful treatment of 13 patients with symphysis rupture with a series of hydrocortisone, chymotrypsin and lidocaine injections. (Schwartz et al., 1985) In that study, however, the diagnosis of symphysis rupture was clinical, and no extent of rupture could be defined. One case report with a radiological gap of 15 mm detailed similar successful injection treatment. (Bonnin et al., 2006) Other methods of non-operative treatment include the use of a pelvic binder and bed rest in a lateral decubitus position. (Herren et al., 2015) In 2017, Mulchandani et al. presented a case where a pubic symphysis rupture with 5.5 cm diastasis was successfully treated with a pelvic binder.

When opting for non-operative treatment, patients should be observed closely for residual symptoms. Kharrazi et al. reported 4 cases from 1997 with a postpartum symphysis pubis rupture ranging from 6.1 cm to 6.6 cm. All patients had accompanying SI joint pain and all but one were treated with a pelvic binder. In six-month follow-up, all patients had residual symptoms and a mean intrapubic gap of 17 mm. The authors suggested that an intrapubic gap of over 6 cm would associate with SI joint pathology and a gap of over 4 cm should be considered a candidate for operative treatment. In other literature, an intrapubic gap of over 2.5 cm was also suggested as an indication for operative treatment by Osterhoff et al. in 2012. In their review, they described operative treatment with an external fixator in 6 cases and internal fixation with anterior plating in 16 cases. Complication rates were 50% in external fixation (pin infection, loss of reduction) and 25% in internal fixation (loss of reduction, implant failure). In 2012, Morris et al. reported hardware breakage in up to 43% of the internal fixations of the pubic symphysis, but most patients remained...
asymptomatic. Anterior symphysial plating can be performed with or without cerclage augmentation. (Hou et al., 2011) For patients with SI joint pain associated with a ruptured pubic symphysis, the first combined antero-posterior surgical approach comprising arthrodesis of the symphysis and both sacroiliac joints was described by R. Hagen in 1974. Rommens published the first description of posterior sacral screw fixation in treating symphysis rupture in 1997. Thereafter, Hierholzer et al. first described the modern option of combining posterior iliosacral percutaneous screw fixation with anterior plate fixation of the pubic symphysis in 2007. Van Zwienen et al. published the results of a 2004 trial detailing the technique of treating chronic cases of severe post-pregnancy pelvic girdle pain with bilateral iliosacral percutaneous screws and symphysiodesis with double plating. In their study, 89% of patients reported clinically relevant symptom relief within 24 months of surgery. Non-union was the most common complication at a rate of 15%. Still, despite several published techniques, no randomised studies have been published regarding the operative or non-operative treatment of pubic symphysis rupture, and current treatment is based on small case series and expert opinion. A review of the current literature concerning the treatment of rupture of the pubic symphysis has been summarised in Table 1.
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Patients</th>
<th>Mode of treatment</th>
<th>Approach</th>
<th>Pain free full weight-bearing</th>
<th>Follow-up</th>
<th>Refractory pain</th>
<th>Complications</th>
<th>Revision surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>Cibils</td>
<td>1</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>12 months</td>
<td>12 months</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1974</td>
<td>Hagen</td>
<td>23</td>
<td>15 conservative with sacroiliac belt, 8 arthrodesis</td>
<td>4 posterior, 2 anterior, 2 combined</td>
<td>17 weeks</td>
<td>72 months</td>
<td>4</td>
<td>Non-union, ankylosis</td>
<td>1 re-arthrodes</td>
</tr>
<tr>
<td>1977</td>
<td>Lindsey et al.</td>
<td>1</td>
<td>Pelvic binder + closed reduction under anaesthesia</td>
<td>N/A</td>
<td>6 months</td>
<td>6 months</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1985</td>
<td>Schwartz et al.</td>
<td>13</td>
<td>Intrasymphysial injection (Corticosteroid + chymotrypsin) once a day</td>
<td>N/A</td>
<td>3 to 7 injections</td>
<td>12 months</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1992</td>
<td>Petersen &amp; Rasmussen</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>N/A</td>
<td>9 months</td>
<td>1</td>
<td>Pin infection</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>Dhar et al.</td>
<td>2</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>3 - 6 months</td>
<td>3 - 6 months</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>1994</td>
<td>Senechal</td>
<td>1</td>
<td>Pelvic sling with 70N weight + Pelvic binder</td>
<td>N/A</td>
<td>4 months</td>
<td>8 months</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1996</td>
<td>Kotwal &amp; Mittal</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>12 weeks</td>
<td>3 months</td>
<td>N/A</td>
<td>Pin infection and loosening</td>
<td>Change to internal fixation N/A</td>
</tr>
<tr>
<td>1996</td>
<td>Kowalk et al.</td>
<td>1</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>38 weeks</td>
<td>38 weeks</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1997</td>
<td>Kharrazi et al.</td>
<td>4</td>
<td>Pelvic binder (3 patients) + closed reduction under anaesthesia (2 patients)</td>
<td>N/A</td>
<td>3 to 6 months</td>
<td>4</td>
<td>0</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1997</td>
<td>Pennig et al.</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>16 weeks</td>
<td>4 months</td>
<td>N/A</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>Rommens</td>
<td>3</td>
<td>Internal fixation</td>
<td>2 posterior, 1 N/A combined</td>
<td>6 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Klotz et al.</td>
<td>1</td>
<td>Internal fixation</td>
<td>Anterior</td>
<td>N/A</td>
<td>12 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>Heath &amp; Gherman</td>
<td>1</td>
<td>Internal fixation</td>
<td>Anterior</td>
<td>N/A</td>
<td>4 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Patients</td>
<td>Mode of treatment</td>
<td>Approach</td>
<td>Pain free full weight-bearing</td>
<td>Follow-up</td>
<td>Refractory pain</td>
<td>Complications</td>
<td>Revision surgery</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------</td>
<td>----------</td>
<td>-------------------------------</td>
<td>-----------</td>
<td>-----------------</td>
<td>--------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>2001</td>
<td>Mau &amp; Jensen</td>
<td>4</td>
<td>2 Internal fixation, 2 external fixation</td>
<td>Anterior</td>
<td>6 - 12 months</td>
<td>6 - 12 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>Culligan et al.</td>
<td>1</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>24 months</td>
<td>24 months</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>2003</td>
<td>Seth et al.</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>12 weeks</td>
<td>3 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>Jain et al.</td>
<td>1</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>N/A</td>
<td>6 months</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>2006</td>
<td>Bonnin et al.</td>
<td>1</td>
<td>Intrasympyseal injection (Lidocaine + corticosteroid) in 48-hour intervals</td>
<td>N/A</td>
<td>2 injections</td>
<td>1 month</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>2007</td>
<td>Hierholzer et al.</td>
<td>1</td>
<td>Internal fixation</td>
<td>Combined</td>
<td>68 weeks</td>
<td>28 months</td>
<td>0</td>
<td>Iliosacral screw lysis</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>Joosoph et al.</td>
<td>1</td>
<td>Abdominal binder</td>
<td>N/A</td>
<td>12 weeks</td>
<td>3 years</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>2008</td>
<td>Chang &amp; Wu</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>4 weeks</td>
<td>18 months</td>
<td>0</td>
<td>Loss of reduction</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>Dunivan et al.</td>
<td>1</td>
<td>External fixation</td>
<td>Anterior</td>
<td>N/A</td>
<td>1.5 months</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>Najibi et al.</td>
<td>10</td>
<td>7 Internal fixation, 3 arthrodesis</td>
<td>Anterior</td>
<td>5 - 160 months</td>
<td>12 - 160 months</td>
<td>0</td>
<td>2 loss of reduction, 2 Implant failure</td>
<td>2</td>
</tr>
<tr>
<td>2011</td>
<td>Hou et al.</td>
<td>1</td>
<td>Internal fixation</td>
<td>Combined</td>
<td>16 weeks</td>
<td>12 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>Osterhoff et al.</td>
<td>2</td>
<td>Internal fixation</td>
<td>Combined</td>
<td>6 to 12 weeks</td>
<td>13 to 22 months</td>
<td>0</td>
<td>1 temporary neurapraxia</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>Mulchandani et al.</td>
<td>1</td>
<td>Pelvic binder</td>
<td>N/A</td>
<td>6 weeks</td>
<td>12 months</td>
<td>0</td>
<td>0</td>
<td>N/A</td>
</tr>
</tbody>
</table>
2.4 Lumbar disc syndrome in young females

Pain in and around the lumbar spine remains one of the most common orthopaedic conditions experienced by parturients. The lumbar spine consists of five lumbar vertebrae. These bony vertebrae are joined anteriorly by intervertebral discs comprising a stiff outer ring, the annulus fibrosus, and a jellylike inner cushion, the nucleus pulposus. Intervertebral discs are found similarly in the whole spine, acting as the primary joint of the entire spinal column. It is in the lumbar spine, however, that they come under the highest loads and strain. Due to these continuous loads and dehydration, intervertebral discs deteriorate with age and the risk of annulus bulge, rupture and eventually herniation of the inner nucleus into the spinal canal increases. (Raj, 2008) The most common symptoms of lumbar disc pathology are related to nerve compression presenting a variety of related symptoms that are distinguishable from general lower back pain. The condition is clinically called lumbar disc syndrome. (Pearce, 1969) Lumbar disc syndrome can occur in any of the lumbar discs, but approximately 95% of all lumbar disc herniations occur in the L4-L5 and L5-S1 joints. (Raj, 2008)

Lumbar disk syndrome is usually self-restricting in symptoms and mostly resolves without interventions. However, both non-operative and operative treatment are prescribed. Medical diagnostics revolve around finding patients that benefit from a specific treatment scheme when symptoms are critical or fail to subside in a reasonable time. (Bailey et al., 2020)

2.4.1 Epidemiology

Lumbar area lower back pain is one the most common symptoms of human life. The reported lifetime prevalence is between 75% and 85%, with an ongoing prevalence of 15% to 30% (Andersson, 1997) Of all patients with lower back pain, only 3% to 4% present with lower limb radiculopathy, with lumbar disc herniation (LDH) being the most common cause (>90%). (Hahne et al., 2010; Koes et al., 2007) A similar prevalence of lumbar disc syndrome of between 4% and 5% has previously been found in the general Finnish
population. (Heliövaara, Impivaara, et al., 1987). Risk factors for lumbar disc syndrome include hard physical strain, older age, obesity, smoking and psychological distress. (Parreira et al., 2018) The incidence of hospitalisation due to LDH or radiculopathy has also been shown to be highest in the middle-aged population with men being at a higher risk than women. (Heliövaara, Knekt, et al., 1987).

For young adults, previously defined trends follow those of the whole population, where males have been shown to be at an increased risk even from a young age. In 1998, Zitting et al. described the cumulative incidence of lumbar disc disease confirmed by magnetic resonance imaging or myelography for females from birth to the age of 28 to be 660 per 100 000 person-years with the first cases of sciatica due to LDH seen at the age of 23. In 1987, Heliövaara, Impivaara, et al. used clinical examination combined with a symptoms questionnaire to describe the prevalence of hospitalised lower back pain-related problems in adults. In their results, the prevalence of lumbar disc syndrome, confirmed by physical examination, in females aged between 30 and 44 years was 3.4%, and the prevalence of a definite LDH confirmed by previous surgery or previous myelography in the Finnish population was 1%.

Lower back pain is a frequent symptom during pregnancy that is reported in up to 70% of all pregnancies, most often between the 20th and 30th weeks of parturition. (Ansari et al., 2010; Fast et al., 1987; Gutke et al., 2008; F. M. Kovacs et al., 2012; S.-M. Wang et al., 2004). While physiological and hormonal changes during pregnancy can predispose the mother to increased lumbar instability, symptomatic lumbar disc herniations during pregnancy are presumed to be rare. However, we are aware of only two studies on symptomatic LDH during pregnancy, one from a single centre study by LaBan et al. in 1983 and the other by O’Connell in 1960. O’Connell reported from a cohort of 179 females, who had borne children and later underwent surgery for LDH, that 39% of the women already had LDH-related radiculopathy symptoms during pregnancy. LaBan et al. reported from a decades-long cohort of almost 50 000 patients that only five cases of symptomatic LDH confirmed by myelography were found for an incidence of 10 per 100 000 person-years, suggesting that LHD is a relatively rare condition when compared to figures from the normal female population of the same age.
For the principal treatment, lumbar discectomy, whole-population incidences were previously reported to be between 170 and 220 per 100 000 person-years in the USA between the years 1992 and 2003. (Weinstein, Lurie, et al., 2006) In the Swedish population, Jansson et al. reported that incidences between the years 1987 and 1999 were approximately 20 per 100 000 person-years. In 2020, Ponkilainen et al. reported the total incidence of lumbar discectomy in young males and females aged 18 to 35 years in the Finnish population declined from 73 per 100 000 person-years in 1997 to 59 per 100 000 person-years in 2018. To the best of our knowledge, however, no previous reports have described the incidence of lumbar discectomy during pregnancy or the puerperal period. The current literature and guidelines are mostly based on single centre case reports and case series with no larger cohort data available.

2.4.2 Diagnostics and classification

Medical science has known sciatic pain as a condition since ancient times. What was first thought of as a peripheral disease of the nerve had already began to evolve into a understanding of the relationship between spinal problems and the lower extremity during the time of the Ancient Greeks. (Marketos & Skiadas, 1999) As understanding of spinal and lower extremity pathology has evolved, so has the examination, evaluation and interrogation of patients with sciatic problems. The largest advances have been made in the past 40 years, with technological advancements enabling the development of new imaging techniques of the spinal canal.

Before modern imaging modalities, the diagnosis of lumbar disc syndrome was based purely on crude clinical symptoms: the presence of sciatic pain reproducible with hip flexion, which formed the basis of the straight leg raise (SLR) test we know today. (Postacchini & Postacchini, 2011) The first imaging techniques were introduced in 1928 by Sicard and Forestier. They developed the first myelography with the suboccipital injection of contrast medium performed by surgeons, after which lateral radiographs were taken by plain X-rays. (Sicard & Forestier, 1933)

Contrast material evolved, but the combination of the SLR test and myelography formed the basis of LDH diagnostics until the 1980s when more clinical examinations and new imaging modalities were introduced.
The crossed-leg raise (XSLR) test together with diminished lower limb reflexes and muscle weakness were defined as good predictors for LDH. (Kosteljanetz et al., 1984) Even today, the combination of the SLR and XSLR tests are considered to have the best clinical specificity for LDH diagnostics in radiculopathy. (van der Windt et al., 2010). Also in the 1980s, the first CT with axial view combined with air myelography revolutionised the imaging field of lumbar disc syndrome. (Tan et al., 1983). These new imaging modalities formed the basis of the first LDH classification nomenclature (anterior, central, posterolateral and far lateral), which is still in use today. The preoperative diagnosis of a far lateral LDH even led to the development of the Wiltse approach. (Wiltse, 1977)

The modern era of lumbar disc syndrome and LDH diagnostics began when the first MRI devices were developed in the early 1990s. The main advantage of MRI was that it allowed the repeated evaluation of the same patient where the development and progression of LDH could be very accurately evaluated. This provided surgeons with a new understanding of the relationship regarding radicular sciatica symptoms and the presence of LDH in imaging modalities. (Postacchini & Postacchini, 2011) In 1994, Jensen et al. demonstrated in the USA that in patients aged between 20 and 80 years, around half had at least one asymptomatic degenerated disk and a quarter had an asymptomatic disk protrusion in lumbar MRI. Takatalo et al. demonstrated in 2009 that in a series of healthy Finnish young adults aged 20 to 22 years, similar results can already be seen at a young age.

Modern diagnostics of lumbar disc syndrome include the presence of both adequate and pathoanatomically coherent clinical symptoms along with a compatible lumbar disk pathology in MRI. Most common clinical symptoms of lumbar disc syndrome include myotomal pain on the side of the compressed nerve root along with diminished reflexes, muscle weakness of the level in question and dermatomal numbness. The SLR test provides high sensitivity, and high specificity can be achieved by combining SLR with the XSLR test. (van der Windt et al., 2010) Regarding MRI results, several different criteria have been developed for the radiological classification and grading of both central spinal canal stenosis and foraminal nerve root compression. (Fardon, 2001; Jensen et al., 1994; Pfirrmann et al., 2004; van Rijn et al., 2005). Of these, the Fardon (commonly referred to as the Combined Task Force [CTF]) and Jensen classifications are most commonly used to describe and evaluate the degree of LDH, whereas the
Pfirrmann and van Rijn classifications are used more for the classification of nerve root compression. Of these, the most commonly used today are the CTF and the van Rijn classification systems, both of which have strong interobserver reliability. (Y. Li et al., 2015). The CTF classification classifies disc pathology into narrow herniations, broad-based herniations and bulges based on whether <25%, 25% to 50% or more than 50% of disc circumference is outside its original boundary. Herniations are then further divided into extrusions and protrusions based on whether the width of the bulging material is wider or narrower than the annular defect from which it arises. The CTF classification further defines sequestrations, which are classified as extrusions that have lost contact with the original disc material. (Fardon, 2001) The van Rijn system for nerve root compression classification uses a scale to divide nerve root compression into five different categories: no root compression, possibly no root compression, indeterminate, possibly root compression and definitely root compression. This categorisation is then dichotomised into two categories where the first three categories fall under no root compression and the latter two under root compression. (van Rijn et al., 2005) These classification systems together with a thorough clinical examination are used to distinguish true lumbar disc syndrome from asymptomatic LDH and other causes of lower back and radicular pain when deciding an individual’s treatment strategy.

2.4.3 Treatment

Weber et al. conducted a randomised trial in 1993 describing the natural progression of sciatic symptoms in which 60% of all patients recovered within three months and 70% within 12 months of symptom onset. For a large portion of patients (up to 30%), however, symptoms persisted for at least a year. This, together with studies demonstrating the causes of sciatica to not only be of mechanical compression but also chemical irritation of disc degeneration, has guided treatment to a primarily more conservative approach. (Marshall & Trehewie, 1973; McCarron et al., 1987; Olmarker et al., 1993) The diagnostic and treatment algorithm for sciatic pain, according to up-to-date knowledge, was published by Koes et al. in 2007.
2.4.3.1 Operative and non-operative treatment

Historically, when clinical assessment was the only mode of diagnosis for sciatica and radiculopathy, all patients with access to a surgeon together with a matching radicular symptom and physical examination were offered surgery. (Kosteljanetz et al., 1984) The main operative technique used was a laminectomy, which was first performed as a surgical procedure in 1887. The first discectomy was subsequently performed in 1908 and the first unilateral laminectomy in 1909. (Alemo & Sayadipour, 2010; Atlas et al., 1996; Patwardhan & Hadley, 2001) Initially, operations were mostly carried out due to paresis, and knowledge of disc pathology was still underdeveloped. The first operation for a diagnosis of ruptured intervertebral disc was performed in 1932 as an L2 – S1 laminectomy. (Mixter & Barr, 1934) Operations were at first transdural and the first extradural intralaminar technique, which forms the basis of open discectomy even today, was performed by Love in 1938. (Love, 1939) Although surgical techniques were refined with growing volumes, major advancements were not seen until the introduction and evolution of myelography when the extent of laminectomy could be narrowed down to just one level. (R. Padua, 1999) Primarily since the 1940s, surgeries were also performed with concomitant lumbar fusion, which was only abandoned at the end of the 1980s. (Kosteljanetz et al., 1984) Further advancements in surgical technique were seen in the 1970s when a surgical microscope was introduced and microscopic discectomy introduced, which quickly became popular in the field of the surgical treatment of LDH. (Williams, 1978; Yasargil et al., 1977).

The rising popularity of discectomy in the treatment of LDH led to the publication of the landmark paper by Weber in 1983 which defined the treatment of LDH. In his study, Weber randomised 126 patients with radiologically confirmed LDH into either operative discectomy or non-operative treatment. His research showed surgical treatment led to earlier symptom relief than in the group of conservatively treated patients. However, after a few years, the differences evened out. The major weakness in Weber’s study was the fact that despite 126 randomised patients, 67 patients were directly operated as “requiring surgical therapy beyond doubt” and 87 patients were treated conservatively due to “lacking surgical indication”. The results of this trial, however, have long been
interpreted to support early surgical relief in lumbar disc syndrome, and for
over two decades it was the only randomised trial on the operative
treatment of LDH.

In the early 21st century, several trials regarding subacute sciatica
emerged. The results of these trials, such as earlier symptom relief with
surgery or remained inconclusive, aligned with those of Weber’s original
trial. (Osterman et al., 2006; Peul et al., 2007; Weinstein, Tosteson, et al.,
2006). Bailey et al. published the first RCT regarding chronic radicular pain
from LDH in 2020. With a duration of more than 4 months, the results of
the trial revealed superior outcomes of pain relief and functionality after
surgery with discectomy.

Several techniques for microendoscopic discectomy have been
developed in an effort to minimise surgical dissection. To date, however,
studies have only shown a clinical benefit with regards to wound infections,
with higher rates or re-hospitalisation due to recurrent herniation. (Rasouli
et al., 2014) Other techniques for the treatment of lumbar disc syndrome
besides surgery have also been developed. The most notable of these has
been chemonucleolysis in which the enzyme chymopapain is injected into
the disc. (Smith, 1964) Although results were favourable, potentially serious
complications, such as anaphylactic shock, have resulted in the method
being discontinued in most western societies with good availability of
discectomy. (Kim et al., 2002)

In current practice, lumbar discectomy is considered a relatively safe
procedure with correct patient selection. Fjeld et al. reported the first
nationwide complication and reoperation rates for lumbar discectomy. Out
of almost 35 000 surgeries, 2.7% of patients suffered a postoperative
complication and 2.1% required reoperation within 90 days of primary
surgery. In the same study, advanced age and accumulating comorbidities
were shown to be risk factors for adverse events after surgery. Smoking has
also been previously demonstrated to be an independent risk factor for
reoperation after lumbar discectomy. (Andersen et al., 2018)

The evolving knowledge regarding the pathophysiology of LDH, its
tendency to settle without operation, but also the good outcomes
associated with surgery in patients with prolonged symptoms have guided
current treatment protocols. A common issue with all studies related to
lumbar disc syndrome is the failure to randomise all patients. Some
phenotypes of symptoms exist that are still considered definite indications
for surgery in the acute phase. These include cauda equina syndrome, a major acute or progressive neurological weakness and incapacitating pain. (Korse et al., 2013). Since the landmark studies of Weber, a period of 6 to 8 weeks of non-operative treatment has been prescribed for other patients with lumbar disc syndrome. In cases where symptoms fail to subside during this time, a diagnostic MRI is indicated and, if diagnosed, LDH is treated operatively.

Several methods for the non-operative treatment of sciatic radiculopathy have been described in the treatment of lumbar disc syndrome. For example, manual traction as well as isometric exercises have been tried but no clear benefit has been demonstrated. (Ljunggren et al., 1992; Mathews et al., 1987) Medications, such as muscle relaxants (Berry & Hutchinson, 1988), non-steroidal anti-inflammatory drugs (Goldie, 1968; H. Weber, 1983; H. Weber et al., 1993) or corticosteroid injections, (Hofferberth et al., 1982; Porsman & Friis, 1979) have also failed to show any benefit when compared to placebo. Physical therapy, when compared to normal activity, has also failed to show any benefit (Coxhead et al., 1981; Hofstee et al., 2002), but so has bed rest. (K. B. Hagen et al., 2005; Vroomen et al., 1999) In conclusion, it seems that currently there is no non-operative treatment that is proven to be superior to no treatment at all.

2.4.3.2 Pregnancy-related factors for treatment indications

Because all published information regarding the treatment of lumbar disc syndrome, cauda equina syndrome and sciatica during pregnancy relies on case reports in the absence of randomised trials, drawing conclusions and guidelines regarding treatment has remained difficult. The most important considerations when discussing lumbar discectomy during pregnancy are to balance the risks and benefits for both the mother and the foetus. (ACOG, 2019; While et al., 2020) Due to the overall increased risk of spontaneous abortion, especially in the first trimester, the ACOG recommends postponing surgery whenever possible to beyond the gestational age of 24 weeks, after which neonatal survival rates after delivery are more than 80%. (Ogawa et al., 2013; Su et al., 2015)

In practice, lumbar discectomy in the pregnant patient differs in both surgical and anaesthesiological aspects from that of the non-pregnant patient. Indeed, the same anaesthesiological considerations as in trauma...
surgery regarding mode and drug exposure apply to lumbar discectomy. Surgically, lumbar discectomy is usually performed in a prone position which, in pregnancy, is possible only during the first and early second trimester. In the second and early third trimester, surgery in a left lateral tilt position is recommended. (Butenschoen et al., 2021; Whiles et al., 2020)

Previous published studies regarding the outcomes of operative and non-operative treatment of lumbar disc syndrome in pregnant women seem to show better outcomes for patients treated non-operatively. (LaBan et al., 1983; Orief et al., 2012; Vougioukas et al., 2004) However, there is only one publication, a case-report, regarding a conservative treatment algorithm for lumbar disc syndrome. (Matsumoto et al., 2009) Moreover, no studies are randomised and most likely suffer from strong selection bias. Patients having stronger residual symptoms after undergoing surgery can probably be explained by more severe preoperative symptoms.

In 2020, Whiles et al. developed a treatment algorithm for lumbar disc syndrome during pregnancy. They acknowledge the presence of the same clinical surgical emergencies in lumbar disc syndrome during pregnancy as in non-pregnant patients, and these phenotypes indicate surgery prioritising the welfare of the mother. In the absence of these severe symptoms, conservative treatment is recommended. If symptoms progress and worsen and lumbar discectomy is indicated, surgery position should be determined by gestational age. In full term pregnancies, a caesarean section in the same setting, prior to discectomy, should be considered. The final decision on operative treatment should always be taken in a multidisciplinary setting.
2.5 Carpal tunnel syndrome in young females

Systemic oedema and hormonal changes in pregnancy are thought to make parturients more susceptible to peripheral neuropathies, the most common of which being carpal tunnel syndrome. First described by Paget in 1865, carpal tunnel syndrome (CTS) is a common peripheral nerve pathology caused by median nerve compression in the wrist. The median nerve is one of the three main nerves supplying motor function and sensation to the hand. In the antebrachium, it travels between the muscle bodies of the flexor digitalis superficialis and the profundus, descending towards the carpal tunnel. (Soubeyrand et al., 2020). The carpal tunnel is an osteofibrous structure which is defined superiorly by the transverse carpal ligament (TCL) and inferiorly by the carpal bones. The TCL attaches to the scaphoid and trapezium on its radial side and the hamate and pisiform on the ulnar, forming the central portion of the flexor retinaculum, which is a distal continuation of the antebrachial fascia. In addition to the median nerve, nine flexor tendons pass through the tunnel into the hand. (Goitz et al., 2014; Tanabe & Okutsu, 1997)

Carpal tunnel syndrome is referred to in the clinical setting of median nerve compression symptoms traceable to the level of the carpal tunnel. Most common symptoms include numbness in the I-IV fingers on the volar side, the dermatomes of the median nerve and thenar weakness. Aetiologies are varied, but the condition remains one of the most diagnosed in orthopaedic and hand surgery. Both operative and non-operative treatments are offered according to symptom severity. (Aboonq, 2015)

2.5.1 Epidemiology

Carpal tunnel syndrome is the most common neuropathy in the whole body, accounting for 90% of all neuropathies. (Aroori & Spence, 2008) First described by Phalen in 1966, the typical patient phenotype is a middle-aged woman. Since then, several studies have reported the incidence of CTS to be higher in females than in males, peaking at around the age of 50 years. (Mondelli et al., 2002; Stevens et al., 1988; Tanaka et al., 1994). Prevalence rates vary between 5% and 16%, depending on diagnostic criteria in the general population. (Atroshi et al., 1999; de Krom et al., 1992). In the
general population of the USA, Nordstrom et al. found the incidence rate of CTS in 1998 to be 346 per 100,000 person-years. Mondelli et al. received similar results from the Italian population in 2002 and found the incidence of carpal tunnel syndrome in the general population to be 276 per 100,000 person-years. Incidence for women was 4:1 with total incidence being 506 per 100,000 person-years, peaking at 50 to 59 years of age. In 2003, Bland & Rudolfer found total female incidence in a British population to be 121 and 62 per 100,000 person-years in two different rural areas.

For young adults, the previously defined epidemiologic behaviour of CTS follows that of the general population where females have higher incidences of CTS from an early age. In the study by Mondelli et al., the incidence of CTS in young females aged 20 to 29 years was just under 200 per 100,000 person-years and around 450 per 100,000 person-years in females aged 30 to 39 years. The results of Bland & Rudolfer were slightly lower, consistent with the values of the general population, ranging from 50 to 150 per 100,000 person-years in females aged 25 to 40 years. Tadjerbashi et al. received similar results from Sweden in 2019 where incidences of CTS in the 20- to 39-year-old population grew steadily with age, ranging from 50 to 250 per 100,000 person-years. In a study by Latinovic et al. from 2006, the incidence of CTS in females younger than 35 years was found to be 82 per 100,000 person-years, rising to 289 per 100,000 person-years in women aged 35 to 44 years.

Pregnancy-related CTS (PRCTS) is one of the most common medical complaints during pregnancy. Although possible in all trimesters, PRCTS usually presents in the third trimester. (Klein, 2013; L. Padua et al., 2010) Melvin et al. published the first incidences of PRCTS in 1969. They found the incidence of PRCTS to vary depending on whether diagnosis was made clinically or electrophysiologically. The incidence of clinical PRCTS was 31% and that of electrophysiologically confirmed PRCT was 7%. Four further studies on the incidence of PRCTS have published similar results where incidence varies depending on the diagnostic criteria and method of diagnostics. (Bahrami et al., 2005; Khosrawi & Maghrouri, 2012; L. Padua et al., 2001; Stolp-Smith et al., 1998) The current literature suggests that the incidence of PRCTS lies somewhere between 33% and 62% when diagnosed clinically and between 7% and 43% when diagnosed electrophysiologically.

The principal operative treatment available for CTS is surgical carpal tunnel release (CTR). The incidence of CTR in the normal female population
has been previously described to be 220 per 100 000 person-years. (Pourmemari et al., 2018) In their study, Tadjerbashi et al. found the incidence of CTR during pregnancy, such as that of Assmus & Hashemi from 2000, are mostly case-series. In 2018, Burton et al. revealed that pregnant women are less likely to undergo CTR for PRCTS than the normal population is for CTS (HR 0.24). However, we are unaware of any published reports on the incidence of CTR during pregnancy or the subsequent puerperal period.

2.5.2 Diagnostics

CTS is caused by increased pressure within the carpal tunnel. This increase in pressure ultimately results in compression and damage to the median nerve. There are several theories as to the exact mechanism of damage, but primarily reversible ischaemia of nerve tissue and subsequent demyelination is thought to be one of the root causes. (Ostergaard et al., 2020) Werner & Andary studied the pressure inside the carpal tunnel and reported normal pressure to vary between 2 mmHg and 10 mmHg. Repetitive movement of the wrist increased the pressure, with the highest in wrist flexion (up to an eight-fold increase). It has been hypothesised that over time these physiological changes and hypoxemia result in the endothelial deterioration of perineural capillaries and subsequently perineural oedema, further increasing the pressure inside the carpal tunnel. Prolonged pathology left untreated results in further permanent neural damage. (Gillig et al., 2016; Ostergaard et al., 2020) Differential diagnostics of CTS include cervical radiculopathy, proximal median nerve compression, thoracic outlet syndrome and polyneuropathies. (Alfonso et al., 2010)

The primary evaluation of CTS is clinical. The first neural fibres affected by the pathophysiological changes are sensory fibres, and these fibres present the first clinical symptoms, which are usually aggravated in wrist flexion. Nocturnal symptoms are usually the first to appear, with symptoms gradually becoming more frequent during the day. The thenar area usually has normal sensation due to its innervation from the palmar cutaneous branch which travels outside the carpal tunnel. (L. Padua et al., 2016) In clinical examination, several tests have been published with varying
sensitivity and specificity. These include the Tinel, Tetro, Phalen, and Durkan tests, with the highest sensitivity and specificity found with the Tetro test. (Durkan, 1991; Seror, 1988; Tetro et al., 1998) For physical examination of the patient, thenar atrophy (96% – 100%), the pinch test (78% – 95%) and grip strength (94%) have been shown to have the greatest specificity. (Dabbagh et al., 2021)

While mildly symptomatic CTS can still be diagnosed and treated purely by clinical examination, it is recommended that all patients with moderate to severe symptoms undergo the combination of a nerve conduction study (NCS) and electromyography (EMG). With a sensitivity of 85% and specificity of 95%, the NCS and EMG are considered good diagnostic tools for the diagnosis of nerve conduction impairment and muscle pathology, while also helping in establishing a preoperative baseline and distinguishing carpal tunnel syndrome from other peripheral neural pathologies. (Alanazy, 2017; Fowler, 2017; Zhuang et al., 2023) For the assessment of primary nerve pathologies and other lesions affecting the median nerve, MRI has emerged as an effective imaging tool. (Kumari et al., 2019)

2.5.3 Treatment

The treatment of carpal tunnel syndrome is varied and includes both operative and non-operative techniques, depending on the severity of the disease. In their review of current evidence from 2016, Graham et al. outlined recommendation strategies for up-to-date treatment, and while effective non-operative treatment methods are available, surgical carpal tunnel release provides the most effective symptom relief at 6- and 12-month follow-up. In their 2020 review and meta-analysis, Shi et al. found corticosteroid injections to be more effective than surgery at 3 months, and splinting more effective at 3- and 12-month follow-up. However, one must also take into account that in 2008 Ortiz-Corredor et al. reported that 29% of patients remained stable and 48% showed an improvement in symptoms in a 2-year follow-up of patients with CTS. The weakness of that study, however, was that in almost all severities of CTS more than half of the patients were lost during the 2-year follow-up. Still, improvement both clinically and electrophysiologically was seen, even in those patients with a thenar motor deficit. In 2005, Kennedy & Zochodne also showed that CTS
progresses more rapidly in patients with predisposing illnesses such as diabetes mellitus and hypothyroidism. Due to conflicting, overlapping and partially lacking results, no straightforward guidelines for the treatment of CTS can be given. Therefore, treatment strategies must be discussed with each individual patient where their previous illnesses and the presentation of symptoms are considered. Local resources also heavily influence treatment protocols. (L. Padua et al., 2022)

2.5.3.1 Operative and non-operative treatment

While the first mention of CTS goes back to 1854, it was not until 1913 that Marie & Foix published the first mention of a thickened transverse carpal ligament. It was in this article that the idea that the surgical dissection of the ligament might relieve symptoms was first proposed. Prior to this, the treatment regime of CTS consisted of therapies such as phosphorus, strychnine, galvanic current, potassium bromide and cannabis. (Putnam, 1880). Moreover, at the beginning of the 20th century, the most common treatment for CTS was removal of the cervical rib. (Pfeffer et al., 1988)

Indeed, it was not until 1933 that the first operation to dissect the transverse carpal ligament was described by Learmonth. Even then, the operation was not performed due to idiopathic CTS but because of posttraumatic symptoms. The first carpal tunnel release for idiopathic CTS was not described by Cannon & Love until 1946. Thereafter, multiple reports followed and surgical treatment soon became popular. (Brain et al., 1947; G. Phalen, 1951; G. Phalen et al., 1950; G. S. Phalen, 1966) Today, the technique described by Learmonth has become the mainstay with multiple minor variances, the only major one being endoscopic release, which was first described by Chow in 1989.

The first randomised trial comparing surgical CTR to non-operative treatment was published by Gerritsen et al. in 2002 where CTR resulted in improved outcomes for patients when compared to splinting. Several randomised trials have since been published that compare CTR to different methods of non-operative treatment. (Awan et al., 2015; Celik & Ilik, 2016; Fernández-de-Las Peñas et al., 2015; Hui et al., 2005; Jarvik et al., 2009; Ly-Pen et al., 2005; Ucan et al., 2006) In a recently published meta-analysis comparing operative treatment with CTR to different non-operative treatment methods, Shi et al. showed a treatment effect favouring CTR at 6
months after surgery, but otherwise results were inconclusive. In open CTR, additional synovectomies or median nerve coverages have not been shown to provide added benefit. (Chiang et al., 2021; de Roo et al., 2021). While slight variations in surgical technique are also common, none have been shown to be superior to the other. Limited evidence supports the use of short-term bulky dressings over long-term ones. (Huisstede et al., 2018; G. Li et al., 2019) The superiority of endoscopic CTR compared to the open technique was studied by Gaspar et al. in 2019 and by Michelotti et al. in 2020, with no added benefit shown to be associated with endoscopic techniques, only added cost.

The most widely used non-operative treatment for CTS is probably splinting. Mansiz Kaplan et al. conducted a randomised trial in 2019 showing the added benefit of kinesiologic taping to splint therapy. To the best of our knowledge, no randomised trials comparing splinting to no therapy have been published. Often added to the non-operative treatment scheme of CTS, local corticosteroid injections have been widely studied. The injections provide symptom relief by decreasing inflammation in the median nerve and its surrounding tissues. In their 2018 randomised study, Chesterton et al. reported a single injection of 20 mg methylprednisolone acetate to be superior in symptom relief compared to a night splint already at 6-week follow-up, with the benefit subsequently persisting for 6 months after the injection. Similar results of superior symptom remission were reported by de Moraes et al. in 2021. In their RCT in 2020, Hsu et al. showed a local injection of 10 mg triamcinolone to be as effective as a 40 mg dose. While unguided local injections have been shown to be effective, injection with ultrasonography guidance seems to provide superior results. (Babaei-Ghazani et al., 2018; H. Wang et al., 2021) Extracorporeal shock wave therapy has also been studied in the treatment of CTS. However, a recent meta-analysis concluded that while remaining a safe treatment, scientific evidence of its benefit is lacking. (W. Li et al., 2020) Two randomised trials have evaluated the use of platelet-rich-plasma (PRP) in the treatment of CTS. (S.-R. Chen et al., 2021; Malahias et al., 2018). The study by Malahias et al. showed improved clinical questionnaire scores with PRP when compared to saline, but Chen et al. failed to show an improvement above the minimum clinically important difference. Anti-inflammatory drugs provide short-term pain relief, but their effect as a
treatment for CTS has not been studied, only as study controls. In this area, more research is needed. (Hamamoto Filho et al., 2009)

2.5.3.2 Pregnancy-related factors for treatment indications

As previously discussed, the incidence of PRCTS seems to be higher than the incidence of CTS in the normal female population. Due to the predisposing factors of pregnancy and the frequent resolution of symptoms after delivery, PRCTS is sometimes thought of as a separate entity from the idiopathic CTS that develops in the normal population. (Klein, 2013; Stolp-Smith et al., 1998) PRCTS is usually managed conservatively with spontaneous full recovery expected, and surgery is reserved for those cases with severe symptoms during pregnancy or with progressing symptoms after delivery. (Massey & Stolp, 2008; Mondelli et al., 2007)

While prevalence of PRCTS is high, there are no reliable data regarding the incidence rates of CTR during pregnancy or the subsequent recovery period. CTR is usually performed under local infiltration anaesthesia, which according to the ACOG guidelines published in 2019 is safe for the foetus irrespective of the trimester. (G. S. Phalen, 1966) However, no recommendations have been published on the treatment of PRCTS. Two cohort studies have been published on the treatment of PRCTS with local corticosteroid injections and, despite possible selection bias, suggest that they are a safe and effective treatment, also during pregnancy. (Moghtaderi et al., 2011; Niempoog et al., 2007) Indeed, corticosteroid injections have been shown to be safe in pregnancy, even in patients with gestational diabetes. (Myrex et al., 2018) We only found one study regarding CTR during pregnancy. Assmus & Hashemi published their results from 314 patients undergoing CTR during pregnancy in 2000. In their cohort, 98% of patients reported good to excellent postoperative outcomes and the operation was well-tolerated for both the mother and the child. However, further evidence to support treatment decisions regarding CTR during pregnancy is lacking and further research is needed in this field.
3 AIMS OF THE STUDY

The overall aim of the present study was to provide the first nationwide results regarding the epidemiology of orthopaedic conditions both during pregnancy and the subsequent recovery period.

The specific aims of the studies were the following:

i. To investigate the incidence and the neonatal outcomes of the fracture hospitalisation and fracture surgery of fertile-aged females during pregnancy compared to the normal female population of a similar age.

ii. To investigate the incidence of fracture hospitalisation and the fracture surgery of fertile-aged females during the first year after delivery when compared to the normal population of a similar age.

iii. To investigate the incidence and perinatal outcomes of vaginal delivery-related rupture of the pubic symphysis.

iv. To investigate the incidence of lumbar disc surgery in fertile-aged females during pregnancy and the first year after delivery compared to the normal female population of a similar age.

v. To investigate the incidence of surgery for peripheral neuropathies in fertile-aged females during pregnancy and the first year after delivery compared to the normal female population of a similar age.
4 MATERIALS AND METHODS

4.1 Study design

This study was a nationwide retrospectively formed register-based cohort study. The study contained data from two different nationwide registers in Finland. The registers used for this study were the Care Register for Health Care and the Medical Birth Register (MBR). Both registers are maintained by the Finnish Institute of Health and Welfare (THL) and supervised by the Finnish Social and Health Data Permit Authority, FinData. Study permits for use of register data are also granted and supervised by FinData. Information gathered from the registers was combined by FinData using a unique pseudonymised key created for each individual patient. FinData retains the pseudonymised key for which the researchers do not have access. The combined study cohort was delivered in a safe remote-controlled environment in compliance with Finnish national General Data Protection Regulation (GDPR) legislation (5.12.2018/1050). The cohort period was from the 1st of January 1998 to the 31st of December 2018.

4.2 Registers

In Finland, personal health register data are gathered nationwide to enable the use of the data for national statistics and research, to improve the quality of national healthcare and guide national health practice. Both registers used in this study were managed by THL, which is a public institution guided by specific legislation (31.10.2008/668). For registers managed by THL, the data are collected from all public and private hospitals, which have a legal obligation to collect and report the required information for the relevant registers. The European GDPR Act (GDPR 2016/679), enforced in 2018, guided the review of Finnish national legislation and led to the creation of the Finnish national GDPR which, together with the Act on National Personal Data Registers kept under the
HealthCare System (556/1989), enabled the control of the use of national health registers for non-governmental research purposes and to allow the use of confidential personal health data in research without the need for private consent.

4.2.1 The Care Register for Health Care

The Care Register for Health Care is a Finnish nationwide register, founded in 1994 as a continuation and expansion of the Hospital Discharge Register, which was originally established in 1969. The Care Register for Health Care is maintained by THL and includes nationwide data on all patients discharged from inpatient care, day surgeries and specialised outpatient care, including emergency room visits. Data on 1.7 million Finnish individuals are reported to the register every year (31% of the Finnish population). (Finnish Institute for Health and Welfare, 2023a). The coverage of the register has previously been shown to be excellent, although reporting of patient comorbidities is lacking. (Mattila et al., 2008; Sund, 2012)

For this study, we extracted data from the Care Register for Health Care on all fertile-aged females (aged 15 to 49 years as defined by WHO) who had sustained an orthopaedic fracture or undergone surgery between 1998 and 2018. To identify fractures, the International Classification of Diseases 10th version (ICD-10) was used, with all patients classified using an S-code for fracture or trauma included in the study cohort. (World Health Organization, 2016) For orthopaedic surgeries, the Nordic Medico-Statistical Committee (NOMESCO) classification was used. (Nordic Centre for Classifications in Health Care, 2010) For our study cohort, we included all operation codes beginning with the letters A or N (neurosurgical and orthopaedic procedures). In our study cohort, we included all the available variables from the register. While providing excellent coverage, the Care Register for Health Care and the ICD-10 and NOMESCO classifications do not distinguish hospitalisations and events into primary and follow-up visits. An up-to-date description of all the variables registered in the Care Register for Health Care is available online in Finnish. (Finnish Institute for Health and Welfare, 2023b)
4.2.2 The Medical Birth Register

The Medical Birth Register (MBR), also managed by THL, was established in 1987. The register consists of data gathered on all the live births and stillbirths of foetuses with a birthweight of at least 500 grams, or an age of at least 22+0 gestational weeks, and their mothers. The MBR has undergone several reforms during its existence, most notably in the years 1990, 1996, 2004 and 2017, with the aim of improving its reliability. The reliability and validity of the register today is excellent. (Finnish Institute for Health and Welfare, 2021)

For this study, we collected all live births and stillbirths from the MBR from 1998 to 2018. Furthermore, we included all available variables from the register in our cohort. However, data on maternal comorbidities were lacking. An up-to-date description of all the variables registered in the MBR is available online in Finnish. (Finnish Institute of Health and Welfare, 2017)

4.3 Patients

From the Care Register of Health Care, we obtained information on a total of 481,412 women who underwent fracture hospitalisation for fracture surgery in a total of 1,334,385 hospitalisations during our study period. From the MBR, we obtained information on 629,921 mothers who had a total of 1,196,330 deliveries during our study period. These cohorts were used to form selective subcohorts for each of the respective studies (I – V) and are described in detail separately.

4.3.1 Study I

For this study on the incidence of fracture hospitalisation and fracture surgery during pregnancy (I), all women aged 15 to 49 years at the time of fracture or surgery were gathered from the Care Register for Health Care to form a preliminary fracture cohort. The study period was from the 1st of January 1998 to the 31st of December 2017. Even though the cohort extended up to the 31st of December 2018, since patients were gathered from the MBR using data on parturition, the study period was narrowed
down to enable the inclusion of all deliveries and pregnancies for the whole study period. The fracture cohort consisted of 481,412 women and a total of 1,235,992 hospitalisations. (Figure 4) To form the pregnancy cohort, we extracted all the pregnancies of women of the same age for the same time period from the MBR. This cohort consisted of 629,921 women and a total of 1,131,439 deliveries. The fracture and pregnancy cohorts were then combined using the pseudonymization key, the date of primary hospitalisation, the date of delivery and pregnancy duration to yield both the final cohort of women who sustained a fracture or who underwent fracture surgery during pregnancy and a control cohort of women who sustained a fracture or underwent fracture surgery outside of pregnancy. During the study period, a total of 1,813 women suffered 2,098 primary fracture hospitalisations during pregnancy. Furthermore, a total of 116,309 women suffered 152,800 primary fracture hospitalisations outside of pregnancy. Due to the limitations of ICD-10 and NOMESCO, we were not able to distinguish between primary fracture hospitalisations, outpatient controls and new hospitalisations due to similar fractures of the contralateral side. Hence, only the first hospitalisation per fracture or operation was considered.

![Flow chart of cohort formation for orthopaedic fractures or operations during pregnancy (I)](image)

Figure 4. Flow chart of cohort formation for orthopaedic fractures or operations during pregnancy (I)
4.3.2 Study II

For this study on the incidence of fracture hospitalisation and fracture surgery during the first year following delivery (II), information on all patients aged 15 to 49 years at the time of fracture or surgery were gathered from the Care Register of Health Care and all pregnancies of women of a similar age from the MBR. The study period was from the 1st of January 1999 to the 31st of December 2018. While the initial cohort included data from 1st January 1998, the first year was cut to ensure the accurate detection of all fractures and fracture surgeries occurring postpartum for the entire study period. During the study period, 466 121 women had a total of 1 283 766 hospitalisations for a fracture or fracture surgery. (Figure 5) A total of 604 526 women had a total of 1 131 439 deliveries. A total of 1 707 pregnancies were excluded from the study cohort due to child mortality within 7 days of delivery. Using a pseudonymization key, the cohorts were combined to yield a fracture cohort of 2 689 women with 3 140 fractures or fracture surgeries during the first year following delivery and a control cohort of 116 309 women with 152 800 fractures or fracture surgeries outside the first year following delivery. As was the case in Study I, distinguishing between primary fracture hospitalisations, outpatient controls and new hospitalisations due to similar fractures of the contralateral side was not possible owing to the limitations of ICD-10 and NOMESCO. As a result, only the first hospitalisation per fracture or operation was considered.
4.3.3 Study III

For this study on the incidence of vaginal birth-related rupture of the pubic symphysis (III), data on all births from the MBR were combined with data from the Care Register for Health Care using the pubic symphysis rupture-specific ICD-10 code “S33.4”. The study period was from the 1st of January 1998 to the 31st of December 2018. Maternal and foetal variables were retrieved from the MBR, whereas data on surgical treatment of the rupture of the pubic symphysis were retrieved from the Care Register for Health Care using pelvis-specific NOMESCO coding. The diagnosis of rupture within 60 days was classified as related to delivery.
4.3.4 Study IV

This study investigated the incidence of lumbar discectomy during pregnancy and the first year after childbirth (IV). Information was obtained on all patients between the ages of 15 and 49 years who had undergone a lumbar discectomy during this period from the Care Register of Health Care. Additionally, data were collected on all pregnancies of women of a similar age from the MBR. The study covered the period from 1 January 1999 to 31 December 2017 to ensure accurate detection of both postpartum surgeries and surgeries occurring during pregnancy for the entire study period. In total, 15 644 women had 16 141 hospitalisations for lumbar discectomy during the study period, while 603 526 women had 1 122 632 deliveries. (Figure 6) Using a pseudonymisation key, cohorts were combined to form a fracture cohort of 89 women who underwent 91 lumbar discectomies during pregnancy, 481 women who underwent 508 lumbar discectomies during the first year after delivery and a control cohort of 13 342 women who underwent 15 426 lumbar discectomies outside of pregnancy and the first year after delivery. In the lumbar discectomy group, one pregnancy was excluded due to infant mortality within seven days of delivery during the first year after delivery. The ICD-10 and NOMESCO systems could not distinguish between primary fracture hospitalisations due to similar operations on another lumbar disc from reoperations, so only the first hospitalisation per operation was considered.
4.3.5 Study V

For the study on peripheral nerve decompression surgery during pregnancy and the first year after childbirth (V), information was gathered from the Care Register of Health Care on all operated patients aged 15 to 49 years during the study period. Additionally, data on all pregnancies of women of a similar age were collected from the MBR. The study covered the period from 1 January 1999 to 31 December 2017 to ensure the accurate detection of both postpartum surgeries and surgeries occurring during pregnancy for the entire study period. In total, 604 526 women underwent at least one pregnancy during the study period, while 24 826 women underwent peripheral nerve decompression surgery. (Figure 7) In total, 1 707 pregnancies were excluded from the study cohort due to child mortality.
within 7 days of delivery. Using a pseudonymisation key, the researchers combined cohorts to form a pregnancy cohort of 308 women who underwent peripheral nerve decompression surgery during pregnancy, a postpartum cohort of 675 women who underwent peripheral nerve decompression surgery during the first year after delivery and a control cohort of 23,651 women who underwent peripheral nerve decompression surgery outside of pregnancy and the first year after delivery. The ICD-10 and NOMESCO systems were unable to differentiate between primary hospitalisations for nerve decompression on the contralateral side from reoperations. As a result, the study considered only the first hospitalisation per operation.

**Figure 7.** Flow chart of cohort formation for peripheral nerve decompression surgery during pregnancy and the first year after delivery (V)
4.4 Statistical methods

4.4.1 Statistics overall

Key figures were calculated to describe patient demographics. To describe continuous variables, means with standard deviations (SD) were calculated for populations that followed a Gaussian distribution, while medians with interquartile ranges were used for populations that did not follow a Gaussian distribution.

Incidence rates per 100 000 pregnancy-years were calculated for applicable studies (I-V). For control cohorts of the similar aged normal population of women (I-II, IV-V), age-adjusted incidence rates per 100 000 person-years were also calculated. Age-adjustment involved determining crude incidence rates for each one-year age group of the normal population and weighting them by the proportion of women in each age group of the postpartum population. The final age-standardised incidence rate was then obtained by summing the weighted crude rates. Incidence rate ratios (IRR) were used to compare the patient cohort to the control. For all incidences and IRRs, 95% confidence intervals (CI) were calculated to demonstrate statistical significance between groups. Poisson regression was used to calculate all incidence rates, IRRs and 95% CIs. To demonstrate temporal onset of a fracture or surgical event, Kaplan-Meier survival analysis was conducted to visualise the timing of the event relative to the number of months after delivery.

For analysis on the incidence of fracture and fracture surgery (I-II), incidents were divided into anatomical subgroups. To estimate the total incidence for these subgroups, a pregnancy length of 39 weeks was assumed, and 95% confidence intervals (CI) were calculated.

All statistical analysis was performed using R version 4.0.3 (R Core Team: A Language and Environment for Statistical Computing, Vienna, Austria).
4.4.2  Pregnancies and deliveries after trauma (I)

Study I analysed the impact of critical fractures and their surgical treatment on pregnancy and delivery. The effect of multiple major fractures was also examined separately. Critical fractures were identified using ICD-10-codes S32.0 to S32.5, S32.7, S32.8, S72.0 to S72.3, and included lumbar column, sacral, iliac, acetabular, pubic, multiple pelvic or lumbar vertebrae and other pelvic, femoral neck, pertrochanteric femoral, subtrochanteric femoral and femoral diaphyseal fractures. To analyse multiple major fractures, all fractures of the torso and proximal limbs were included. Patients with simultaneous multiple pelvic fractures were classified under code S32.7 irrespective of primary coding. The study also calculated incidence and operation incidences with 95% CIs, preterm delivery rates and mortality rates. Trauma-related preterm delivery was defined as delivery before 37 gestation weeks within seven days of trauma. The classification was devised specifically for this study, as there were no applicable definitions given in previous studies. Fractures were considered surgically treated if fracture surgery was performed within 14 days of the first hospitalisation. For this analysis, only pregnancies over 22 gestation weeks were included since the Finnish Birth Register does not record earlier gestation data.

4.4.3  Osteoporotic fractures after pregnancy (II)

In Study II, a separate analysis of fractures occurring in the spinopelvic region and traditional osteoporotic fracture sites during the first year after delivery was performed. Spinopelvic and osteoporotic fractures were identified using ICD-10-codes S22.0, S32.0 to S32.5, S32.7, S32.8, S33.4, S72.0 to S72.3, S42.2, S52.5 and included thoracic and lumbar column, sacral, coccygeal, iliac, acetabular, pubic, multiple pelvic or lumbar vertebrae, other pelvic, femoral neck, pertrochanteric femoral, subtrochanteric femoral, femoral diaphyseal, proximal humeral and distal radius fractures along with traumatic ruptures of the pubic symphysis. For these fractures, incidences with 95% CIs and operation percentages were calculated. Fractures were categorised as surgically treated if fracture
surgery was performed within 14 days of the first hospitalisation. Patients with multiple pelvic fractures occurring simultaneously were analysed with code S32.7, regardless of the primary coding.

4.4.4 Revision surgery (IV – V)

In the cohort, the chronologically first operation was determined as the primary one if a patient underwent several operations with the same operation code during the follow-up period. The time elapsed between operations was then calculated. Any surgery carried out within 90 days of the primary operation was classified as a revision operation. Logistic regression was used to calculate the odds ratios (OR) for risk of revision surgery, and the results were reported along with their CIs.

4.4.5 Risk factors for surgery (IV – V)

Multivariable logistic regression was used to assess the age-adjusted effect of maternal smoking on risk of lumbar discectomy or peripheral nerve decompression. Information on maternal smoking was obtained from the MBR. Comorbidities and other risk factors were not selected for analysis since they are not accurately reported in the registers used. Results are reported as ORs with 95% CIs.
4.5 Ethics and permissions

4.5.1 Ethics of the study

As per the Finnish National Board on Research Integrity, which is appointed by the Ministry of Education and Culture, research involving public and published data, registry and documentary data, and archive data do not require a formal ethics committee review under Finnish research legislation. Nevertheless, our study was carried out in accordance with the ethical principles outlined in the World Medical Association Declaration of Helsinki and adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies. (von Elm et al., 2007)

4.5.2 Research permission

In compliance with the Finnish national General Data Protection Regulation (GDPR) issued on 5.12.2018/1050, data processing was permissible for scientific research purposes even without written consent from the data subjects. The amount of data and the number of subjects makes it impractical to obtain consent from every individual, and the research could not have been conducted without identifying information. The study was authorized by the Finnish Health and Social Data Permit Authority FinData, with permission number THL/1756/14.02.00/2020.
5  SUMMARY OF THE RESULTS

5.1  Incidence of fracture hospitalisation during pregnancy (I)

During the 20-year study period, 1813 pregnant women were admitted to hospital with a fracture diagnosis, and a total of 2098 fractures were documented in this population. The mean age of all patients was 29.6 (±5.7) years. The cumulative 20-year incidence for fractures was 247 per 100 000 person-years (CI 237 to 259), and for fracture surgery it was 61 per 100 000 person-years (CI 56 to 67). Of all the fractures, 24% (n=513/2098) underwent operative treatment, and the annual incidence rates for fractures ranged from 204 to 313 per 100 000 person-years. (Figure 8) The corresponding operation rates varied from 33 to 86 per 100 000 person-years. In the normal population of women, the respective 20-year incidence rates for all fractures and fracture surgery were 554 per 100 000 person-years and 150 per 100 000 person-years, respectively. The total age-adjusted fracture incidence for the normal population was 553 per 100 000 person-years (95% CI 536 to 572) with a total IRR of 0.34 (CI 0.33 to 0.34), and 30% of all fractures were treated operatively. The in-hospital maternal mortality due to trauma was low, with three mothers dying due to trauma (incidence 0.2 per 100 000 pregnancies, CI 0 to 0.6). Severe traumatic brain injury was the primary cause of death in all cases. The rate of stillbirth due to trauma was 0.9 per 100 000 pregnancies (CI 0.4 to 1.6, 0.5% of fracture patients, n=10/2098), which was 1.2-fold higher than the stillbirth rate in the general population of women in Finland.
The tibia and ankle were the most frequent anatomical sites of fracture (incidence of 70.1 /100 000), with distal tibial and fibular fractures of the ankle comprising 67% of all cases (n=399/595). (Table 2) Forearm fractures had an incidence rate of 54.9 /100 000, with distal radius fractures accounting for 54% (n=253/466) of all cases. The highest rate of surgery was found in thigh fractures (50%, n=13/26), followed by tibia and ankle fractures (42%, n=250/595). The incidence of pelvic fractures was 6.8 per 100 000 person-years (CI 4.0 to 6.7), and the rate of surgical treatment was 14% (n=8/59), which was the third lowest rate after skull fractures (0%, n=0/114) and spine fractures (6%, n=6/102). All fracture types were more common in the normal population when compared to pregnant women. The incidence profile of fractures by anatomical location in the normal population was similar to that of pregnant women, with tibia and ankle and forearm fractures being the most common. The largest proportional decrease was observed in thigh fractures, with the fracture rate in the normal population being 3.6-fold higher. The smallest difference was seen in pelvic fractures, with the fracture rate in the normal population being 1.8-fold higher compared to the pregnant population.
Table 2. Incidences of fractures and their operations divided by anatomical location. Incidences reported as fractures or operations per 100 000 person-years.

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Fractures</th>
<th>Surgery</th>
<th>Fractures</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incidence (95% CI)</td>
<td>Incidence (95% CI)</td>
<td>Incidence (95% CI)</td>
<td>Incidence (95% CI)</td>
</tr>
<tr>
<td>Head</td>
<td>13.44 (11.01 to 16.13)</td>
<td>0 (0 to 0.44)</td>
<td>41.2 (36.46 to 46.4)</td>
<td>0.40 (0.09 to 1.23)</td>
</tr>
<tr>
<td>Spine</td>
<td>12.03 (9.8 to 14.59)</td>
<td>0.82 (0.33 to 1.69)</td>
<td>27.93 (24.05 to 32.26)</td>
<td>4.01 (2.74 to 5.92)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>6.83 (5.29 to 8.97)</td>
<td>0.69 (0.25 to 1.53)</td>
<td>12.53 (10.0 to 15.51)</td>
<td>1.98 (1.10 to 3.36)</td>
</tr>
<tr>
<td>Brachium</td>
<td>19.56 (16.69 to 22.67)</td>
<td>1.77 (0.99 to 2.92)</td>
<td>48.52 (43.36 to 54.13)</td>
<td>14.30 (11.63 to 17.42)</td>
</tr>
<tr>
<td>Forearm</td>
<td>54.92 (50.03 to 60.13)</td>
<td>6.72 (5.09 to 8.71)</td>
<td>120.79 (112.56 to 129.47)</td>
<td>24.25 (20.74 to 28.22)</td>
</tr>
<tr>
<td>Hand</td>
<td>33.23 (29.47 to 37.35)</td>
<td>6.24 (4.68 to 8.17)</td>
<td>84.26 (77.4 to 91.57)</td>
<td>27.94 (24.17 to 32.18)</td>
</tr>
<tr>
<td>Thigh</td>
<td>3.01 (2.0 to 4.49)</td>
<td>1.41 (0.73 to 2.47)</td>
<td>10.85 (8.49 to 13.67)</td>
<td>5.46 (3.88 to 7.52)</td>
</tr>
<tr>
<td>Tibia and ankle</td>
<td>70.12 (64.6 to 75.87)</td>
<td>25.33 (22.07 to 28.96)</td>
<td>150.81 (141.62 to 160.45)</td>
<td>64.98 (59.16 to 71.26)</td>
</tr>
<tr>
<td>Foot</td>
<td>12.37 (10.12 to 14.97)</td>
<td>3.77 (2.56 to 5.32)</td>
<td>33.70 (29.42 to 38.44)</td>
<td>15.15 (12.41 to 18.36)</td>
</tr>
<tr>
<td>Total</td>
<td>247.24 (236.77 to 258.05)</td>
<td>46.79 (42.29 to 51.63)</td>
<td>553.36 (353.56 to 571.60)</td>
<td>149.85 (140.91 to 159.23)</td>
</tr>
</tbody>
</table>
A total of 39 patients experienced critical fractures during pregnancy, resulting in an incidence rate of 4.6 per 100 000 person-years (CI 3 to 6). (Table 3) The rate of surgery was 21% (n=8/39). These incidences were much lower than those in the normal population where the total incidence was 30.5 per 100 000 person-years. Multiple major fractures of the torso or proximal limbs occurred with an incidence of 1.6 per 100 000 person-years (CI 1 to 3) with a surgery rate of 9% (n=1/11). Among patients who experienced critical fractures, preterm delivery occurred in 21% (n=8/39), and stillbirth in 10% (n=4/39) of cases. The most common fracture was a lumbar spinal column or sacral fracture (n=7, incidence 0.8 per 100 000 person-years), followed by multiple spinal and pelvic fractures (n=6, incidence 0.7 per 100 000 person-years), other fractures of the pelvis (n=5, incidence 0.6 per 100 000 person-years), and fractures of the femoral neck (n=4, incidence 0.5 per 100 000 person-years).

Notably, fractures of the lumbar spine, which were the most common single critical fracture in pregnant women, showed the most significant decrease in incidence, remaining more than ten-fold smaller compared to the general population. Critical fractures resulted in preterm delivery in 14% of cases (n=10/82). Among subtrochanteric fractures (n=2), femoral shaft fractures (n=2), and sacral fractures (n=7), the surgery rate was 50%, 50% and 29% (n=2/7), respectively. The stillbirth rate was 0% (n=0/11). In cases of multiple pelvic fractures (n=6), the rate of surgery was 33% (n=2/6), the preterm birth rate was 33% (n=2/6) and the stillbirth rate was 17% (n=1/6). Most lumbar spine fractures were treated non-operatively (rate of surgery 14%, n=1/7), resulting in preterm birth in 29% of cases (n=2/7), and the stillbirth rate was 14% (n=1/7). In total, lumbosacral and comminuted spinopelvic fractures resulted in preterm delivery in 25% (n=5/20) of parturients, with a stillbirth rate of 10% (n=2/20). All isolated fractures of the acetabulum and pubis were treated non-operatively until delivery with no preterm births or stillbirths.
Table 3. Incidences per 100 000 person-years of major fractures of the spinopelvic area divided by anatomical location (ICD-10 code) and multiple major fractures of the torso. Rates of surgical treatment, preterm delivery and foetal mortality are shown as a percentage of the total count.

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Count</th>
<th>Incidence (95% CI, Surgical treatment %)</th>
<th>Preterm Delivery (%)</th>
<th>Stillbirth (%)</th>
<th>Normal population incidence (95% CI, Surgical treatment %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of lumbar vertebra</td>
<td>7</td>
<td>0.83 (0.33 to 1.69, 14%)</td>
<td>29</td>
<td>14</td>
<td>10.49 (8.17 to 13.26, 9%)</td>
</tr>
<tr>
<td>Fracture of sacrum</td>
<td>7</td>
<td>0.83 (0.33 to 1.69, 29%)</td>
<td>14</td>
<td>0</td>
<td>2.86 (1.73 to 4.46, 7%)</td>
</tr>
<tr>
<td>Fracture of acetabulum, pubis and ilium</td>
<td>6</td>
<td>0.71 (0.25 to 1.53, 0%)</td>
<td>0</td>
<td>0</td>
<td>4.67 (2.37 to 8.45, 10%)</td>
</tr>
<tr>
<td>Multiple fractures of lumbar spine and pelvis</td>
<td>6</td>
<td>0.71 (0.25 to 1.53, 33%)</td>
<td>33</td>
<td>17</td>
<td>2.78 (1.67 to 4.44, 20%)</td>
</tr>
<tr>
<td>Fracture of other parts of pelvis</td>
<td>5</td>
<td>0.59 (0.19 to 1.37, 0%)</td>
<td>0</td>
<td>0</td>
<td>2.12 (1.17 to 3.54, 5%)</td>
</tr>
<tr>
<td>Fracture of neck of femur</td>
<td>4</td>
<td>0.47 (0.13 to 1.12, 25%)</td>
<td>25</td>
<td>0</td>
<td>2.78 (1.67 to 4.36, 29%)</td>
</tr>
<tr>
<td>Per-, and subtrochanteric femur fractures and femoral shaft fractures</td>
<td>4</td>
<td>0.47 (0.13 to 1.12, 50%)</td>
<td>50</td>
<td>50</td>
<td>4.82 (2.6 to 8.52, 32%)</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>4.6 (3.27 to 6.28, 21%)</td>
<td>21</td>
<td>10</td>
<td>30.52 (26.47 to 35.03, 16%)</td>
</tr>
<tr>
<td>Multiple major orthopaedic fractures</td>
<td>14</td>
<td>1.65 (0.91 to 2.77, 7%)</td>
<td>14</td>
<td>7</td>
<td>24.27 (20.66 to 28.33, 36%)</td>
</tr>
</tbody>
</table>
5.2 Incidence of fracture hospitalisation during the first year after delivery (II)

In study II, 2689 women experienced hospitalisation due to one or more fracture diagnoses within the first year after childbirth, amounting to a total of 3140 fractures. The mean age of the postpartum women was 30 years (±5.7), compared to 33 years (±10.8) for the normal population. The incidence rate of fracture hospitalisation over 20 years was 280 per 100 000 person-years (CI 270 to 290), while for fracture surgery it was 87 per 100 000 person-years (CI 82 to 93). During the first four months after delivery, the incidence of fracture hospitalisation was 220 per 100 000 person-years (CI 205 to 235), which increased to 310 per 100 000 person-years during the subsequent eight months (CI 297 to 323). Of all fractures, 29% (n=904/3140) required operative treatment. Annual incidence rates ranged from 205 to 381/100 000 person-years for fracture hospitalisation and from 67 to 126 per 100 000 person-years for fracture surgery. (Figure 9) In the normal population of women, the 20-year incidence rate for all hospitalised fractures was 554 per 100 000 person-years and 150 per 100 000 person-years for fracture surgery. Postpartum women had a lower incidence of fractures than the normal population with a total IRR of 0.51 (CI 0.47 to 0.54). (Table 4) In the normal population, 30% of all fractures were treated operatively. Fractures occurred steadily within the 12-month follow-up period after delivery, with a mean onset at 6.6 months after delivery. (Figure 10) The incidence of fracture hospitalisation increased in the immediate postpartum period, stabilised, and then slowly increased towards the end of the 12-month follow-up period.
Table 4. IRR of fractures and fracture surgery of postpartum women and the normal population during the first year after delivery.

<table>
<thead>
<tr>
<th>Time After Delivery</th>
<th>Fracture IRR (95% CI)</th>
<th>Fracture Surgery IRR (95% CI)</th>
<th>Fracture Incidence Postpartum</th>
<th>Fracture Surgery Incidence Postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 12 months</td>
<td>0.51 (0.47 to 0.54)</td>
<td>0.58 (0.51 to 0.66)</td>
<td>279.7</td>
<td>87.47</td>
</tr>
<tr>
<td>0 to 4 months</td>
<td>0.40 (0.36 to 0.44)</td>
<td>0.44 (0.36 to 0.53)</td>
<td>219.66</td>
<td>65.47</td>
</tr>
<tr>
<td>4 to 12 months</td>
<td>0.56 (0.52 to 0.60)</td>
<td>0.59 (0.51 to 0.67)</td>
<td>309.72</td>
<td>87.92</td>
</tr>
</tbody>
</table>

Figure 9. Yearly incidence (per 100,000 person-years) of fracture hospitalisation and surgery during the first year after delivery in Finland between 1999 and 2018 and their 95% confidence intervals.
The forearm was the most common anatomical location for hospitalised fractures during the first four months after delivery with an incidence rate of 56 per 100,000 person-years. (Table 5) This was followed by the tibia and ankle with an incidence rate of 55 per 100,000 person-years, and the hand with an incidence rate of 29 per 100,000 person-years. Fractures of the distal radius accounted for 60% of all forearm fractures, while fractures of the distal tibia accounted for 64% of all fibula, tibia and ankle fractures. The incidence of pelvic fractures requiring hospitalisation was 15 per 100,000 person-years, and 22% of these cases required surgical treatment. Incidence rates for all anatomical locations increased between four and 12 months after delivery, except for pelvic fractures which displayed a higher incidence rate during the first four months. The pelvic fracture hospitalisation incidence rate decreased to 9 per 100,000 person-years during the 12-month follow-up period. The incidence rate of fracture surgery increased from 65 per 100,000 person-years to 88 per 100,000 person-years, except for fractures of the head, spine and pelvis where the incidence rate decreased.

When compared to the postpartum population, all fracture locations were more common in the normal population, except for pelvic fractures.
The tibia and ankle were the most common fracture sites in the normal population, with an incidence rate of 151 per 100,000 person-years, followed by the forearm with an incidence rate of 121 per 100,000 person-years. The incidence rate of hospitalised fractures of the thigh was 2.6 times higher in the normal population than in postpartum women (incidence rate of 11 per 100,000 person-years). Fracture surgery incidence rates were also higher in the normal population for all fractures, except for those of the pelvis where the incidence rate was similar between the postpartum population and the normal population.

During the initial 12 months following pregnancy, a total of 852 spinopelvic and fractures of typical osteoporotic sites were observed, yielding an overall incidence of 76 per 100,000 person-years (CI 71 to 81) (Table 6). The total incidence of fracture hospitalisation in the first four months after delivery was 69 per 100,000 person-years (CI 61 to 78, n=257), which then rose by 16% during the subsequent eight months to 80 per 100,000 person-years (CI 73 to 86). However, the incidence rates of fractures remained lower than those observed in the normal population (127 per 100,000 person-years, CI 104 to 159). The incidence of fracture surgery after delivery remained relatively stable, starting at 17 per 100,000 person-years at four months (CI 13 to 22, 25%) and then increasing slightly to 21 per 100,000 person-years at 12 months (CI 17 to 24, 26%). Overall, the surgical rate was comparable to that of the general population with an incidence of 36 per 100,000 person-years (30%, CI 25 to 55).

Most fractures showed a slight increase in hospitalisation incidence between the first four months and the subsequent eight months. The most significant increase was observed in traditional osteoporotic fracture locations, including the thoracic spine, distal radius, proximal humerus and proximal femur. However, even with these increases, the incidence rates remained lower than those in the normal population. The incidence of fracture hospitalisation due to a fracture of the thoracic spine increased from 2.1 per 100,000 person-years (CI 0.9 to 4.2) to 3.6 per 100,000 person-years (CI 2.4 to 5.3). Similarly, the incidence of proximal humerus and distal radius fracture hospitalisations increased from 6.4 per 100,000 person-years (95% CI 4.1 to 9.5) to 10 per 100,000 person-years (95% CI 8.1 to 13) and from 33 per 100,000 person-years (95% CI 28 to 40) to 45 per 100,000 person-years (95% CI 41 to 51), respectively.
However, multiple spinopelvic and comminuted fractures had a higher incidence rate of 3.2 per 100,000 person-years (CI 1.7 to 5.6) at four months after delivery. Interestingly, this incidence rate declined to 2.5 per 100,000 person-years at 12 months after delivery (CI 1.5 to 4.0). This was the only fracture category with a higher incidence during the first four months after delivery compared to that of the general population. For these fractures, the incidence of fracture surgery increased from 0.3 per 100,000 person-years (CI 0.0 to 1.5, 8%) at four months to 1.1 per 100,000 person-years (CI 0.5 to 2.1, 42%) at 12 months. All traumatic ruptures of the symphysis pubis occurred during the first 4 months after delivery (n=11/11), with an incidence of 2.9 per 100,000 person-years (CI 1.5 to 5.3), a surgical rate of 55% (n=6/11) and mean fracture onset of 34 days after delivery (+42). Furthermore, all traumatic fractures of the symphysis pubis occurred after vaginal delivery.

### Table 5.
Incidences of fractures and fracture surgeries during the first 4 and the latter 8 months of the first year after delivery divided by anatomical location. Incidences reported as fractures or operations per 100,000 person-years.

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Fracture incidence (95% CI) 0 to 4 months after delivery</th>
<th>Fracture incidence (95% CI) 4 to 12 months after delivery</th>
<th>Fracture surgery incidence (95% CI) 0 to 4 months after delivery</th>
<th>Fracture surgery incidence (95% CI) 4 to 12 months after delivery</th>
<th>Fracture incidence (95% CI) Normal population 0 to 4 months after delivery</th>
<th>Fracture incidence (95% CI) Normal population 4 to 12 months after delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>11.22 (8.09 to 15.17)</td>
<td>21.11 (17.95 to 24.67)</td>
<td>0.13 (0.01 to 0.74)</td>
<td>41.22 (36.48 to 46.43)</td>
<td>0.40 (0.09 to 1.23)</td>
<td>4.09 (2.74 to 5.92)</td>
</tr>
<tr>
<td>Spine</td>
<td>12.56</td>
<td>15.23 (12.56 to 18.3)</td>
<td>0.8 (0.29 to 1.74)</td>
<td>27.94 (24.06 to 32.28)</td>
<td>4.09</td>
<td>1.99 (2.74 to 5.92)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>14.7</td>
<td>9.22 (7.17 to 11.67)</td>
<td>1.34 (0.64 to 2.46)</td>
<td>12.53 (10.00 to 15.52)</td>
<td>1.99</td>
<td>1.10 (2.74 to 5.92)</td>
</tr>
<tr>
<td>Brachium</td>
<td>18.44</td>
<td>26.46 (22.9 to 30.41)</td>
<td>6.55 (4.84 to 8.66)</td>
<td>48.56 (43.40 to 54.17)</td>
<td>14.31</td>
<td>11.64 (17.43)</td>
</tr>
<tr>
<td>Forearm</td>
<td>56.39</td>
<td>78.3 (72.09 to 84.9)</td>
<td>17.9 (22.9 to 30.41)</td>
<td>120.91 (112.67 to 129.59)</td>
<td>24.27</td>
<td>20.76 (28.24)</td>
</tr>
<tr>
<td>Hand</td>
<td>28.86</td>
<td>46.36 (29.66 to 72.09)</td>
<td>18.04 (22.9 to 30.41)</td>
<td>84.30 (77.44 to 91.61)</td>
<td>27.96</td>
<td>20.76 (28.24)</td>
</tr>
<tr>
<td>Thigh</td>
<td>4.01</td>
<td>4.14 (3.88 to 7.52)</td>
<td>2.67 (2.67 to 4.14)</td>
<td>3.88 (2.67 to 4.14)</td>
<td>4.47</td>
<td>3.88 (2.67 to 4.14)</td>
</tr>
<tr>
<td>Tibia and ankle</td>
<td>54.78</td>
<td>75.36 (69.27 to 81.84)</td>
<td>36.08 (31.9 to 40.65)</td>
<td>150.98 (141.77 to 160.62)</td>
<td>65.04</td>
<td>59.12 (71.31)</td>
</tr>
<tr>
<td>Foot</td>
<td>12.03</td>
<td>21.91 (18.69 to 25.54)</td>
<td>4.8 (4.67 to 10.77)</td>
<td>33.72 (34.40 to 54.17)</td>
<td>15.16</td>
<td>12.42 (18.37)</td>
</tr>
<tr>
<td>Total</td>
<td>219.66</td>
<td>309.72 (297.24 to 322.59)</td>
<td>87.92 (81.33 to 94.9)</td>
<td>553.80 (434.20 to 572.05)</td>
<td>149.96</td>
<td>141.02 (159.34)</td>
</tr>
</tbody>
</table>

Postpartum women

Normal population
Table 6. Incidences of fractures and fracture surgeries and the surgical rates of spinopelvic and typical osteoporotic fractures during the first 4 and the latter 8 months of the first year after delivery. Rates of surgical treatment are shown as a percentage of the total count.

<table>
<thead>
<tr>
<th>Anatomical Location</th>
<th>Postpartum women</th>
<th></th>
<th>Normal population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 to 4 months after delivery</td>
<td>4 to 12 months after delivery</td>
<td>Normal population</td>
</tr>
<tr>
<td></td>
<td>Fracture incidence (95% CI)</td>
<td>Fracture surgery incidence (95% CI, surgical rate)</td>
<td>Fracture incidence (95% CI)</td>
</tr>
<tr>
<td>Fracture of</td>
<td>2.14 (0.92 to 4.21)</td>
<td>0.27 (0.01 to 1.49, 12%)</td>
<td>3.61 (2.38 to 5.25)</td>
</tr>
<tr>
<td>thoracic spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>5.88 (3.68 to 8.9)</td>
<td>1.6 (0.59 to 3.49, 27%)</td>
<td>5.21 (3.71 to 7.12)</td>
</tr>
<tr>
<td>lumbar spine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>3.74 (2.05 to 6.28)</td>
<td>0 (0 to 0.09, 0%)</td>
<td>3.74 (0 to 0.74, 4%)</td>
</tr>
<tr>
<td>coccyx</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>6.41 (4.11 to 9.54)</td>
<td>1.34 (0.43 to 3.12, 21%)</td>
<td>10.29 (8.12 to 12.86)</td>
</tr>
<tr>
<td>proximal humerus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>33.67 (28.05 to 40.09)</td>
<td>7.22 (4.75 to 10.5, 21%)</td>
<td>45.43 (40.73 to 50.52)</td>
</tr>
<tr>
<td>distal radius</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>1.6 (0.59 to 3.49)</td>
<td>1.6 (0.59 to 3.49, 100%)</td>
<td>1.07 (0.46 to 2.11)</td>
</tr>
<tr>
<td>neck of the femur</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pterotrochanteric fracture</td>
<td>0.27 (0.01 to 1.49)</td>
<td>1.6 (0.01 to 1.49, 100%)</td>
<td>0.53 (0.15 to 1.37)</td>
</tr>
<tr>
<td>Subtrochanteric fracture</td>
<td>0.27 (0.01 to 1.49)</td>
<td>0 (0 to 0.09, 0%)</td>
<td>0.27 (0 to 0.74, 50%)</td>
</tr>
<tr>
<td>Fracture of</td>
<td>1.07 (0.29 to 2.74)</td>
<td>1.6 (0.17 to 2.34, 75%)</td>
<td>1.6 (0.83 to 2.8)</td>
</tr>
<tr>
<td>femoral shaft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>2.14 (0.92 to 4.21)</td>
<td>0.27 (0.01 to 1.49, 12%)</td>
<td>1.60 (0.83 to 2.8)</td>
</tr>
<tr>
<td>sacrum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>0.27 (0.01 to 1.49)</td>
<td>0 (0 to 0.09, 0%)</td>
<td>0.53 (0.15 to 1.37)</td>
</tr>
<tr>
<td>ilium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>1.87 (0.75 to 3.85)</td>
<td>1.07 (0.29 to 2.74, 57%)</td>
<td>0.27 (0.03 to 0.97)</td>
</tr>
<tr>
<td>acetabulum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracture of</td>
<td>1.60 (0.59 to 3.49)</td>
<td>0 (0 to 0.09, 0%)</td>
<td>1.60 (0.83 to 2.8)</td>
</tr>
<tr>
<td>pubis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other fracture of pelvis</td>
<td>1.60 (0.59 to 3.49)</td>
<td>0 (0 to 0.09, 0%)</td>
<td>1.20 (0.83 to 2.8)</td>
</tr>
<tr>
<td>Traumatic fracture of symphysis pubis</td>
<td>2.94 (1.47 to 5.26)</td>
<td>1.6 (0.59 to 3.49, 55%)</td>
<td>0 (0 to 0.49)</td>
</tr>
<tr>
<td>Multiple pelvic fractures</td>
<td>3.21 (1.66 to 5.6)</td>
<td>0.27 (0.01 to 1.49, 8%)</td>
<td>2.54 (1.53 to 3.96)</td>
</tr>
<tr>
<td>Total</td>
<td>68.68 (60.54 to 77.61)</td>
<td>16.84 (12.94 to 21.54, 25%)</td>
<td>79.50 (73.24 to 86.15)</td>
</tr>
</tbody>
</table>
5.3 Incidence of vaginal delivery-related rupture of the pubic symphysis (III)

Throughout our study period, there were a total of 9 cases of pubic symphysis injuries that occurred during the intrapartum and puerperal periods, and 4 of these required surgical intervention. All the surgeries were conducted during the initial hospitalisation period for the women. The incidence rate of ruptures was 0.8 per 100 000 deliveries (CI 0.4 to 1.5), whereas the incidence rate of operations was 0.3 per 100 000 deliveries (CI 0.1 to 0.9). When looking at vaginal deliveries separately, the incidence rate of ruptures was 0.9 per 100 000 deliveries (CI 0.4 to 1.7), and the incidence rate of operations was 0.4 per 100 000 deliveries (CI 0.1 to 1.0). All cases of symphysis pubis ruptures that were diagnosed during the intrapartum and puerperal periods occurred after vaginal delivery with a mean birthweight of 3605 g and no perinatal mortality observed. (Table 7)

Outside of the intrapartum and puerperal periods, a total of 19 cases of symphysis pubis rupture required hospitalisation during the 21-year study period. The mean cohort size of women during each year of the study was 1 181 104. Out of these 19 cases of symphysis pubis rupture, 8 women had previously undergone vaginal delivery, and 7 nulliparous women had concurrent major fractures at the time of rupture.
Table 7. Characteristics of women sustaining birth-related symphysis pubis rupture injury and the neonatal outcomes of pregnancies.

<table>
<thead>
<tr>
<th></th>
<th>During pregnancy (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age (mean + sd)</td>
<td>32 ± 4</td>
</tr>
<tr>
<td>Maternal height (mean + sd)</td>
<td>162cm ± 8</td>
</tr>
<tr>
<td>Maternal weight (mean + sd)</td>
<td>66kg ± 19</td>
</tr>
<tr>
<td>Primipara (n + %)</td>
<td>4 (44%)</td>
</tr>
<tr>
<td>Gestational age, weeks (mean + sd)</td>
<td>40+5 ± 1</td>
</tr>
<tr>
<td>Vaginal delivery (n + %)</td>
<td>9 (100%)</td>
</tr>
<tr>
<td>Operative vaginal delivery (n + %)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Singleton births (n + %)</td>
<td>9 (100%)</td>
</tr>
<tr>
<td>Epidural analgesia (n + %)</td>
<td>7 (78%)</td>
</tr>
<tr>
<td>Time (days) from delivery to injury (mean + sd)</td>
<td>15.9 ± 15</td>
</tr>
<tr>
<td>Perinatal mortality (n + %) 1</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Birthweight (mean + sd)</td>
<td>3605g ± 741g</td>
</tr>
<tr>
<td>Head circumference (mean + sd)</td>
<td>35cm ± 2</td>
</tr>
<tr>
<td>Apgar score (median + IQR) 2</td>
<td>9 [9, 9]</td>
</tr>
<tr>
<td>Maternal smoking (0 + %)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

1 Stillbirths and deaths before age of 7 days, 2 One-minute Apgar Score
5.4 Incidence of lumbar disc surgery during pregnancy and within 12 months postpartum (IV)

Between the years 1999 and 2017, a total of 91 lumbar discectomy operations were performed during pregnancy, and 508 were performed within the 12 months postpartum period in Finland. The mean age for patients who underwent lumbar discectomy during pregnancy was 30.6 (±5.1) years and 31.3 (±4.8) years for those who underwent the surgery within 12 months postpartum. (Table 8) The yearly incidence rates remained stable throughout the follow-up period. Moreover, the study observed fewer than 5 discectomy operations for thoracic and cervical disc herniations over the entire study period. The mean age of the control population was 37.2 (±8.0) years.

Table 8. Characteristics of women undergoing lumbar discectomy during pregnancy and the neonatal outcomes in these pregnancies.

<table>
<thead>
<tr>
<th>During pregnancy (n = 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age, mean (SD)</td>
</tr>
<tr>
<td>Primipara, n (%)</td>
</tr>
<tr>
<td>Gestational age, weeks (mean + SD)</td>
</tr>
<tr>
<td>Vaginal delivery (n + %)</td>
</tr>
<tr>
<td>Epidural analgesia (n + %)</td>
</tr>
<tr>
<td>Weeks at time of surgery (mean)</td>
</tr>
<tr>
<td>Perinatal mortality (n + %) 1</td>
</tr>
<tr>
<td>Birthweight (mean + SD)</td>
</tr>
<tr>
<td>Apgar score (median + IQR) 2</td>
</tr>
<tr>
<td>Maternal smoking (n + %)</td>
</tr>
</tbody>
</table>

1 Stillbirths and deaths before age of 7 days, 2 One-minute Apgar Score

The 19-year total incidence of lumbar discectomy during pregnancy was 11 operations per 100 000 pregnancy-years (CI 9 to 14) with yearly incidence rates varying significantly between 5 and 21 per 100 000 person-
years. (Figure 11) The control population had a total incidence rate of 69 operations per 100 000 person-years (CI 68 to 70), resulting in an IRR of 0.2 (CI 0.1 to 0.2). The 90-day reoperation rates for women who underwent discectomy during pregnancy were lower (1.1%) than for those women in the control population (2.2%), with an IRR of 0.5 (CI 0.1 to 3.5).

Figure 11. Incidence (per 100 000 person-years) of lumbar discectomy during pregnancy in Finland between the years 1999 and 2017 with 95% confidence intervals.

The majority of lumbar discectomies were performed during the first 2 trimesters of pregnancy with a mean pregnancy duration of 15+3 weeks at the time of surgery. (Figure 12) Only 12% of operations were performed during the third trimester. No foetal mortality was observed among women who underwent discectomy during pregnancy. However, caesarean section was more frequent after lumbar discectomy during pregnancy (22%) than in pregnant women without the surgery (17%). The mean pregnancy duration was 39+5 (±1) gestational weeks with 36% of women being primiparas. The mean birthweight (SD) was 3592 (±544) grams. Caesarean section was performed during the same hospitalisation period as the discectomy in fewer than 5 cases. About 27% of women who underwent lumbar
discectomy during pregnancy were active smokers before pregnancy (n=24/89), whereas the respective figure for all pregnant women during the study period was 17%. Furthermore, active smokers before pregnancy were at a higher risk for lumbar discectomy during pregnancy (OR 2.0, CI 1.2 to 3.2).

**Figure 12.** Temporal occurrence of lumbar discectomy during pregnancy visualised by a Kaplan-Meier survival graph.
In the first 12 months postpartum, the incidence of lumbar discectomy was 47 operations per 100,000 person-years. However, the annual incidence varied greatly, ranging from 29 to 81 per 100,000 person-years during the follow-up period. The IRR between lumbar discectomy within the first 12 months postpartum and the control population was 0.7 (CI 0.6 to 0.8). (Figure 13)

Compared to the control population, the 90-day reoperation rate for women within 12 months postpartum was 3.7% with an IRR of 1.7 (CI 1.1 to 2.7). The incidence of discectomy increased slowly towards the end of the first year following delivery with the mean occurrence of the operation at 6.8 months postpartum. (Figure 14)
In the first 12 months postpartum, the incidence of lumbar discectomy was 47 operations per 100,000 person-years. However, the annual incidence varied greatly, ranging from 29 to 81 per 100,000 person-years during the follow-up period. The IRR between lumbar discectomy within the first 12 months postpartum and the control population was 0.7 (CI 0.6 to 0.8). (Figure 13)

Figure 13. Incidence (per 100,000 person-years) of lumbar discectomy within the first 12 months postpartum in Finland between the years 1999 and 2017 with 95% confidence intervals.

Compared to the control population, the 90-day reoperation rate for women within 12 months postpartum was 3.7% with an IRR of 1.7 (CI 1.1 to 2.7). The incidence of discectomy increased slowly towards the end of the first year following delivery with the mean occurrence of the operation at 6.8 months postpartum. (Figure 14)

Figure 14. Temporal occurrence of lumbar discectomy within 12 months postpartum visualised by a Kaplan-Meier survival graph.

Of those women who underwent lumbar discectomy within the first 12 months post-delivery, 18% were active smokers before becoming pregnant (n=86/481). The risk of lumbar discectomy in women who were active smokers before pregnancy was similar to that of non-smokers (OR 1.1, CI 0.9 to 1.4). However, there were odds for revision surgery within 90 days during the first year after delivery with an OR of 2.0 (CI 0.6 to 5.4).
5.5 Incidence of carpal tunnel release during pregnancy and the first year after delivery (V)

In study V, we found that over a period of 19 years, 308 women underwent CTR during pregnancy and 675 within the first year after delivery, representing 1% and 3% of all operated women, respectively. The mean age of patients who underwent CTR during pregnancy was 31.4 (±5.2) years, and 33.0 (±5.2) years for those who underwent CTR during the first year after delivery. The yearly incidence rates remained stable during pregnancy, but there was an increasing trend seen in CTR during the first year after delivery. In comparison, a total of 23 651 females underwent CTR (96% of all operated women) in the control population with a mean age of 40.3 (±7) years. We also observed 10 ulnar nerve release procedures during pregnancy and 16 during the first 12 months after delivery.

The incidence of CTR during pregnancy was found to be 38 per 100 000 (CI 34 to 43) person-years between 1999 and 2017 with annual rates ranging from 23 to 56 per 100 000 person-years. (Figure 15) The total incidence rate for the control population was 77 per 100 000 (CI 70 to 84) person-years, resulting in an IRR of 0.5 (CI 0.4 to 0.6). During pregnancy, carpal tunnel release was most frequently performed during the first trimester with an average pregnancy duration of 15.6 weeks at the time of surgery. (Figure 16) Furthermore, only 16% of operations were carried out during the third trimester. During the study period, the percentage of pregnant women who smoked before pregnancy was 17%. However, 25% of women who underwent carpal tunnel release during pregnancy were active smokers before becoming pregnant (n=76/308). Active smokers before pregnancy had a higher risk of carpal tunnel release during pregnancy (OR 2.4, CI 1.8 to 3.0). Previous pregnancies did not increase the likelihood of carpal tunnel surgery during pregnancy (OR 1.04, CI 0.8 to 1.4).
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We also observed 10 ulnar nerve release procedures during pregnancy and 16 during the first 12 months after delivery. The incidence of CTR during pregnancy was found to be 38 per 100,000 (CI 34 to 43) person-years between 1999 and 2017 with annual rates ranging from 23 to 56 per 100,000 person-years. (Figure 15) The total incidence rate for the control population was 77 per 100,000 (CI 70 to 84) person-years, resulting in an IRR of 0.5 (CI 0.4 to 0.6).

During pregnancy, carpal tunnel release was most frequently performed during the first trimester with an average pregnancy duration of 15.6 weeks at the time of surgery. (Figure 16) Furthermore, only 16% of operations were carried out during the third trimester. During the study period, the percentage of pregnant women who smoked before pregnancy was 17%. However, 25% of women who underwent carpal tunnel release during pregnancy were active smokers before becoming pregnant (n=76/308). Active smokers before pregnancy had a higher risk of carpal tunnel release during pregnancy (OR 2.4, CI 1.8 to 3.0). Previous pregnancies did not increase the likelihood of carpal tunnel surgery during pregnancy (OR 1.04, CI 0.8 to 1.4).

Figure 15. Incidence (per 100,000 person-years) of carpal tunnel release during pregnancy in Finland between 1999 and 2017 with 95% confidence intervals.

Figure 16. Temporal occurrence of carpal tunnel release during pregnancy visualised in a Kaplan-Meier survival graph.
During our 19-year follow-up, the incidence of CTR during the first year after delivery was 63 per 100 000 person-years (CI 58 to 68). The yearly incidence rates varied greatly during this period, ranging from 35 to 95 per 100 000 person-years. (Figure 17) The IRR for CTR in women during the first year after delivery compared to the control population was 0.8 (CI 0.7 to 1.0).

Figure 17. Incidence (per 100 000 person-years) of carpal tunnel release during the first 12 months after delivery in Finland between 1999 and 2017 with 95% confidence intervals.

The incidence of CTR was low immediately after delivery but increased during the first four months postpartum and subsequently reached the same level of incidence as the general population during the following eight months. On average, surgery was performed 7.2 months postpartum. (Figure 18) In the first year after delivery, the incidence of CTR during the first four months postpartum was 32 per 100 000 person-years (CI 26 to 38), increasing to 79 per 100 000 person-years (CI 72 to 85) in the latter eight months. The IRR for CTR in the last eight months of the 12 months after delivery compared to the control population was 1.0 (CI 0.9 to 1.2). Of the women who underwent CTR during the first 12 months after delivery, 17% were active smokers before pregnancy (n=118/675). The risk for CTR in...
During our 19-year follow-up, the incidence of CTR during the first year after delivery was 63 per 100,000 person-years (CI 58 to 68). The yearly incidence rates varied greatly during this period, ranging from 35 to 95 per 100,000 person-years. (Figure 17) The IRR for CTR in women during the first year after delivery compared to the control population was 0.8 (CI 0.7 to 1.0).

Figure 17. Incidence (per 100,000 person-years) of carpal tunnel release during the first 12 months after delivery in Finland between 1999 and 2017 with 95% confidence intervals.

The incidence of CTR was low immediately after delivery but increased during the first four months postpartum and subsequently reached the same level of incidence as the general population during the following eight months. On average, surgery was performed 7.2 months postpartum. (Figure 18) In the first year after delivery, the incidence of CTR during the first four months postpartum was 32 per 100,000 person-years (CI 26 to 38), increasing to 79 per 100,000 person-years (CI 72 to 85) in the latter eight months. The IRR for CTR in the last eight months of the 12 months after delivery compared to the control population was 1.0 (CI 0.9 to 1.2). Of the women who underwent CTR during the first 12 months after delivery, 17% were active smokers before pregnancy (n=118/675). The risk for CTR in women who were active smokers before pregnancy was higher than that of non-smokers (OR 1.6, CI 1.3 to 1.9).

Figure 18. Temporal occurrence of carpal tunnel release during the first 12 months after delivery visualised in a Kaplan-Meier survival graph.
6 DISCUSSION

6.1 Incidence of fractures leading to hospitalisation

In our nationwide studies (I, II), we found that between 1998 and 2017 there were 247 fractures per 100 000 person-years leading to hospitalisation during pregnancy in the whole population of Finland. Out of these, roughly one fifth required operative treatment, resulting in 61 operations per 100 000 person-years and a yearly nationwide mean of 27 operations. After delivery, the total incidence of fractures leading to hospitalisation during the first 12 months was 280 fractures per 100 000 person-years with one fourth of these fractures requiring operative treatment. The incidence of fracture hospitalisation increased after the first four months following delivery, rising from 220 per 100 000 person-years during the first four months to 310 per 100 000 person-years during the latter eight months of the first postpartum year. This resulted in an IRR of 0.56 (95% CI 0.56 to 0.57) when compared to the age-adjusted female normal population. Most fracture rates remained lower in the normal population, but the incidence of pelvic fractures during the first 4 months after delivery was similar. Fractures of the tibia, ankle and forearm were the most common fractures both during pregnancy and during the postpartum year, making up half of all fractures and most of the operations. The maternal in-hospital mortality was low.

Although there are no existing data on the occurrence of fractures and fracture surgery during pregnancy or the first year after delivery, several population-based studies have reported the incidence of fractures among women, including a Scottish study by Court-Brown & Caesar in 2006 and a Swedish study by Bergh et al. between 2015 and 2018, which found rates of 1 065 and 1 413 per 100 000 person-years, respectively. In these studies, both emergency department visits and hospitalisations were taken into account. Another study by Farr et al. from 2017, which included both inpatient and outpatient data, reported a total fracture incidence of 1 135 per 100 000 person-years among women aged 18 to 49 years in Minnesota,
USA. Fractures also have different age distributions for men and women. In men, the incidence follows a parabolic distribution with a bias towards younger and older age groups. In contrast, the incidence of fractures in women remains relatively constant with a slow increase with age until a rapid increase after menopause. Our study found that the incidence of fractures in pregnant and postpartum women was lower than that of the general population across all age groups.

Lower incidences of hospitalised fractures for pregnant and postpartum women could be partially explained by lower risk taking behaviour and activity levels. In their study, Farr et al. found that at 71% high energy trauma was the most common cause of fractures with occupational- (30%) and recreational-related (18%) incidents, falls from height (14%) and motor vehicle accidents (10%) being the most frequent mechanisms. In females aged 18 to 49 years, falls from standing height accounted for 22% of all fractures with a male to female ratio of 1:2. The foot and hand were the most affected body parts, contributing to 40% of all fractures. In contrast, our study demonstrated a different pattern with ankle, distal radius and proximal humerus fractures being more common in both patient groups. However, the previous findings regarding injury mechanism support the theory of lower risk taking behaviour and activity levels during pregnancy and the postpartum period. The greatest reduction in incidence was observed in thigh fractures which are almost exclusively high-energy injuries in the working population. (Enninghorst et al., 2013; R. J. Weiss et al., 2009) Additionally, pregnant women are advised to avoid physically demanding activities involving body contact or sudden movements, and they spend more than half of their time in a sedentary position. (Fazzi et al., 2017; Mottola et al., 2018) Pregnant and breastfeeding women are also advised to abstain from alcohol, which has been identified as a risk factor for traumatic events. (Riuttanen et al., 2020) The lower incidence rates of hospitalised fractures suggest that transient pregnancy-induced osteoporosis-related fractures may not be clinically significant during pregnancy. These fractures, which affect the femur, pelvis and lumbar spine, are typically diagnosed postpartum after radiological and behavioural restrictions have been lifted and have been shown to recover slowly after delivery. (Emami et al., 2012; Fingeroth, 1995; Willis-Owen et al., 2008; Wood, Larson, et al., 2003) However, we found that pelvic fractures were more common during the first 4 months of the first year after delivery,
suggesting the possible clinical relevance of transient osteoporosis during this period. Reports of conditions originating during pregnancy but only being diagnosed after delivery raises the possibility of fractures being left underdiagnosed in pregnant women. However, the development and spread of modern MRI techniques will probably alleviate these concerns. (Clements et al., 2000) Surgery for pelvic fractures was also more frequent during this period. The combination of weight gain, transient hypocalcaemia and changes related to lactation may increase physical susceptibility to trauma during the first few months postpartum. (C. S. Kovacs, 2014; C. S. Kovacs & Ralston, 2015; Winter et al., 2020) In Finland, mothers are advised to gradually resume daily activities after 2 months postpartum, which aligns with our findings that the incidence of fractures increases towards 12 months after delivery, with over half occurring between 6 and 12 months postpartum. (Lucia-Casademunt et al., 2018) This increase may be due to the long-term effects of lactation and calcium mobilisation as well as increased physical activity stress after the initial postpartum period. (Maliha et al., 2012; Winter et al., 2020)

The surgical rates observed in our study were consistent with the previously reported rates in the general population. (Beerekamp et al., 2017; Court-Brown & Caesar, 2006; Lundin et al., 2021; Ponkilainen et al., 2020; Rinne et al., 2020) However, our study revealed lower surgical rates for pelvic fractures in pregnant women compared to both the general population and the previously reported rates for high-energy pelvic fractures which are known to be more common in younger individuals. (Balogh et al., 2007; Mann et al., 2018) This finding suggests that surgeons may exercise greater caution when considering surgery for pregnant women with pelvic and femoral fractures. According to H. B. Weiss et al. from 2001, the rate of foetal death due to maternal trauma is 2.3 per 100 000 live births, and pelvic fractures during pregnancy have been associated with a foetal death rate as high as 35%. Although the total stillbirth rate of all fractures in our study was 0.9 per 100 000 pregnancies (0.6%), the stillbirth rate for comminuted spinopelvic and lumbosacral fractures was relatively high at 10%. It should be noted, however, that the total count for this specific figure remained low, leading to uncertainty in the interpretation and conclusions.
6.2 Rupture of the pubic symphysis

Based on our findings in study III, the occurrence of pubic symphysis ruptures related to childbirth needing orthopaedic intervention is rare with an incidence rate of 0.8 ruptures per 100 000 deliveries. Moreover, pubic symphysis ruptures are typically linked with vaginal delivery. These statistics are the first comprehensive incidence rates reported nationwide and are lower than previously reported rates. As the primary diagnostic criterion for pubic symphysis rupture is a sufficiently expanded radiological intrapubic diameter, there is no distinction made between partial and complete ligamentous ruptures in the diagnosis. The lack of an established treatment algorithm for these injuries supports our findings that ruptures are often managed non-operatively. From our data, we cannot distinguish the specific cause of the rupture, but it was the only traumatic diagnosis within 60 days of delivery for all women. It is possible, therefore, that our data may only include radiologically confirmed ruptures and could be limited to highly symptomatic cases, which would be a potential drawback in our results.

6.3 Lumbar disc surgery

During our nationwide study (IV), the incidence of lumbar discectomy was lower among pregnant women and those within the first year postpartum compared to the control population of the same age. The cumulative incidence during pregnancy was 11 operations per 100 000 person-years and 47 operations per 100 000 person-years during the first 12 months after delivery. For pregnant women, the immediate reoperation rate was lower than the control population with an IRR of 0.5, but higher during the first 12 months after pregnancy with an IRR of 1.7. Most lumbar discectomies (88%) were conducted during the first two trimesters. In comparison to the entire study population, women who underwent lumbar discectomy during pregnancy had a higher rate of caesarean section.

As previous studies have not reported the occurrence of lumbar discectomy during pregnancy or the postpartum period, it is challenging to compare our results to those of prior investigations. However, previous studies have reported lumbar discectomy rates for the general population
of 170 to 220 per 100 000 person-years in the USA and around 20 per 100 000 person-years in Sweden. (Jansson et al., 2004; Weinstein, Lurie, et al., 2006) A recent study by Ponkilainen et al. from 2021, which used the same registers as in the present study, reported a decrease in the incidence of lumbar discectomy in male and female patients aged 18 to 35 years in Finland from 73 to 59 per 100 000 person-years between 1997 and 2018, which is consistent with our findings for young females in the general population. Additionally, previous studies have reported a 90-day reoperation rate after lumbar discectomy of 1.4% to 2.0% for patients aged 18 to 39 years, which is slightly lower than our reported rate of 2.2% for the general young female population, but supports our findings of a higher 90-day reoperation rate of 3.7% postpartum. (Fjeld et al., 2019) The 90-day reoperation rates during pregnancy were lower at 1.1%. The caesarean section rate in Finland has previously been reported to be 16.6%, which is slightly lower than the rate found in the women who underwent lumbar discectomy during pregnancy in our study. (Pallasmaa et al., 2010) Our results revealed that smoking rates (27%) were higher among women who underwent lumbar discectomy during pregnancy than in the general female population of the same age (17%). (Finnish Institute of Health and Welfare, 2018) Furthermore, women with a history of smoking were at a higher risk for lumbar discectomy during pregnancy.

The findings of our study support our hypothesis and are consistent with previous reports that indicate a lower incidence of lumbar discectomy during as opposed to outside pregnancy. Pregnancy-related anatomical and hormonal changes can increase the instability of the lumbar discs. However, operating on a pregnant woman requires careful consideration due to several concerns that require multidisciplinary planning. (ACOG, 2019) The technical implementation of lumbar discectomy during pregnancy involves different patient positioning and anaesthesia management compared to non-pregnant patients. (Ardaillon et al., 2018; Whiles et al., 2020) For example, during the first and early second trimesters, the prone position can be used, but during the late second and third trimesters left lateral tilt positioning is recommended. Caesarean section immediately before discectomy can also be considered in advanced pregnancies. (Ardaillon et al., 2018; Butenschoen et al., 2021) These factors, along with the low level of evidence, could result in a reluctance to operate as the pregnancy progresses, possibly explaining the lower reoperation rates in pregnant
women. Although we could not specify the specific indications for surgery in our patients, the lower incidence of lumbar discectomy during pregnancy and the first year following delivery may be due to conservative treatment in milder cases of disc herniation. Our findings show a slight reduction in the rate of lumbar discectomy after the first trimester with an even greater reduction in the third trimester when surgery may be limited to emergency scenarios only. No foetal mortality was observed in our study, and newborns had normal Apgar scores and gestational age after lumbar discectomy during pregnancy.

Previous studies have demonstrated that smoking is a risk factor for lumbar disc herniation, which is consistent with our finding of a higher risk for lumbar discectomy among mothers who smoked before pregnancy. (Huang et al., 2016) In addition, smoking has been identified as an independent risk factor for reoperation, which is also supported by our results. (Andersen et al., 2018)

After childbirth, surgical limitations related to the foetus are removed, but the impact of anaesthesia should be considered during lactation. In Finland, exclusive breastfeeding is recommended for the first 4 months, followed by complementary breastfeeding for up to 12 months after delivery. (Finnish Institute for Health and Welfare, 2019) The hormone relaxin, which affects connective tissue metabolism, remains in the mother's body after delivery. (Kristiansson et al., 1996; MacLennan et al., 1986) This may partly explain the lower incidence of lumbar discectomy during the initial months after delivery, which appears to increase towards the end of the first year. Furthermore, the effects of relaxin and increased lumbar movement may also contribute to the increased reoperation rates observed in the postpartum period through possible re-herniation.
6.4 Carpal tunnel release

In our nationwide study (V), we found that the rate of CTR among pregnant women was lower than that of the control group of the same age with an IRR of 0.5. The incidence of CTR was the highest during the first trimester and decreased as the pregnancy progressed for a cumulative incidence of 38 operated women per 100 000 person-years. After delivery, the incidence of CTR gradually increased and reached the same level as the control group in the last 8 months of the first 12 months after delivery. The cumulative incidence for the 12 months after delivery was 63 operated women per 100 000 person-years. The risk of CTR during and after pregnancy was higher for women who actively smoked before pregnancy. We observed only isolated cases of operations for other peripheral neuropathies during pregnancy and the initial 12-month postpartum period.

Due to the absence of published data on the occurrence of CTR during pregnancy or in the year following delivery, we cannot directly compare our findings to those of previous studies. Nevertheless, Burton et al. noted in 2018 that pregnant women were less likely to undergo CTR (HR 0.24, CI 0.21 to 0.28). In 2006, Latinovic et al. reported the incidence of CTS in women younger than 35 years to be 81.5 per 100 000 person-years, while it was 289 per 100 000 person-years in women aged between 35 and 44 years. In 2018, Pourmemari et al. reported the incidence of CTR to be 220 per 100 000 person-years in the general female population. Smoking has previously been identified as a risk factor for CTS with a HR of 1.5 to 1.9 for women, which is consistent with our findings of a higher incidence of CTR during and after pregnancy for women who smoked before pregnancy. (Hulkkonen et al., 2019)

Our study also found a lower incidence of CTR during pregnancy compared to females of a similar age in the general population which supports our hypothesis and previous research. The lower incidence of CTR in our age-matched control population can be explained because CTS is most prevalent between the ages of 40 and 60 years. (Bongers et al., 2007; Genova et al., 2020; Latinovic et al., 2006) During pregnancy, hormonal and physiological changes make pregnant women more susceptible to developing CTS with fluid build-up in the carpal tunnel being the most proposed cause. However, changes in insulin resistance and other hormones may also play a role in pregnancy-related CTS. (L. Padua et al.,
years. In 2018, Pourmemari et al. reported the incidence of CTR to be 220 per 100,000 person-years in the general female population. Smoking has previously been identified as a risk factor for CTS with a HR of 1.5 to 1.9 for developing CTS with fluid build-up in the carpal tunnel being the most prevalent between 40 and 60 years. In 2006, Latinovic et al. reported the incidence of CTS in pregnant women younger than 35 years to be 81.5 per 100,000 person-years, while it was 289 per 100,000 person-years in the general population which is consistent with our findings of a higher incidence of CTR for motor deficit, sensory loss or when persistent pain prevents sleep. (Graham et al., 2016; L. Padua et al., 2022) In addition to the preference for non-operative treatment of CTS during pregnancy, spontaneous recovery is typically expected, which probably contributes to the lower rates of CTR when compared to the general population. This may also explain why the incidences of CTR increase to the level of those of the general population after the first 4 months postpartum when pregnancy-related CTS symptoms are typically decreasing. Our findings also show a significant decrease in the rate of CTR after the first trimester. Postoperative rehabilitation involves wearing dressings for various lengths of time and discouraging patients from lifting or straining the operated hand for several weeks, which limits some of the mother's physical abilities. (Cowan et al., 2012; Peters et al., 2016) These factors can influence the surgeon's decision to pursue non-operative treatment both during pregnancy and the immediate postpartum period. During our study period, there was a significant fluctuation in the yearly incidence of CTR with a notable increase towards the end of the study period. This trend was observed across all groups, including pregnant women, postpartum women and the general population, suggesting that the increase was likely due to an increase in the general popularity of CTR. In the past, smoking has been identified as a potential risk factor for CTS. (Hulkkonen et al., 2019) However, studies have also linked smoking with CTS due to atherosclerotic changes and a potential ischemic mechanism. Furthermore, smoking can also impede recovery from peripheral nerve damage. (Rinker et al., 2011; Shiriri et al., 2011) Our study revealed that women who smoked before pregnancy had a higher risk of acquiring CTR. This risk was even higher during pregnancy and persisted throughout the first year after childbirth. These findings support previous research indicating that smoking is a risk factor for CTR during pregnancy and the subsequent recovery period.
6.5 Strengths and limitations

6.5.1 Study strengths

One of the primary strengths of our study is the extensive national coverage provided by the Care Register for Health Care. This is further complemented by the high national coverage of the Medical Birth Register which is estimated to cover 100% of all pregnancies. (Finnish Institute for Health and Welfare, 2021; Gissler et al., 1995; Huttunen et al., 2014) This enabled us to collect comprehensive nationwide data on fractures, fracture surgery, lumbar discectomies and CTR operations among fertile-aged women with minimal selection bias, encompassing all operations performed in both public and private hospitals. In addition, the comprehensive coverage of our cohort allowed us to compile unique national data on fractures requiring hospitalisation during pregnancy and the resulting delivery outcomes. This enabled us to present the first national epidemiological figures for these conditions, which are also the largest to date. Another strength is our long study period that spanned 21 years.

6.5.2 Study limitations

Our study has several limitations regarding hospitalisation and surgery for fractures during pregnancy and the first year after childbirth. As the primary limitation, the Finnish national Birth Register records only pregnancies with a viable foetus (≥22 weeks), meaning that we could not include fractures that resulted in termination of pregnancy before this time. However, as it is surrounded by soft tissue, the foetus is relatively well protected in the womb before 22 weeks. Second, the Care Register for Health Care includes only hospitalised fractures. Hence, minor fractures that are non-operatively treated in primary healthcare settings or private clinics are not comprehensively recorded. Finally, the diagnostic criteria for pubic symphysis rupture are primarily based on radiological intrapubic diameter,
and our data could not distinguish between partial and total ligamentous rupture. Although all women in our study had radiologically verified ruptures of the symphysis pubis within 60 days of delivery, it is likely that our figures only include highly symptomatic cases.

In relation to lumbar discectomies during pregnancy and the first 12 months after delivery, our data have a primary limitation in that only surgical procedures were included, and we were unable to examine patients who received conservative treatment. Additionally, a secondary limitation is that we were unable to account for patients' comorbidities, such as diabetes, in our analyses.

The primary limitation of our study on CTR is the exclusion of patients who received non-surgical treatment for CTS, thus limiting our analysis to only surgically treated patients. Therefore, our findings reflect only the incidence of surgical intervention and do not provide insights into the severity or duration of symptoms. Additionally, we were only able to account for the first CTR performed per patient, which prevented us from analysing bilateral CTR or revision surgery. Our data did not include information on maternal body mass index, profession or miscarriages before 22 weeks of gestation, which again limits the scope of our analysis. Finally, we were unable to examine the impact of possible comorbidities on our results due to the limitations of our data.
7 SUMMARY AND CONCLUSIONS

Our study aimed to contribute novel insights into the incidence of prevalent orthopaedic disorders during pregnancy and the first 12 months after delivery. We conducted a cohort study using data from two national registers for the years 1998 to 2018. Further, we examined the incidence of fracture hospitalisation and surgery, lumbar discectomy and CTR and compared it to the normal population of women of a similar age range. In the following sections, we present the key results and conclusions of each study:

i. The incidence of fracture hospitalisation in pregnant women is lower than in the normal population, and non-surgical treatment is more common. Women with lumbosacral and comminuted spinopelvic fractures have a higher rate of preterm deliveries and stillbirths. Total maternal mortality and stillbirth rates remain low.

ii. Although fracture hospitalisation rates increased gradually during the first year after delivery, they remained lower than in the normal population. However, a higher incidence of pelvic fractures was observed in the first few months after delivery. Surgical rates were similar to those in the normal population.

iii. Birth-related ruptures of the pubic symphysis are rare events mostly associated with vaginal delivery and are often treated non-operatively.

iv. Lumbar discectomy during pregnancy is rare, but smoking increases the risk. Moreover, lumbar discectomy during pregnancy seems to be safe for the neonate. Postpartum incidences increased towards the end of the first year but remained below the rates seen in the general population with a higher risk for short-term reoperation.
v. The incidences of CTR in women decrease during pregnancy. However, incidences gradually increase during the postpartum period, becoming comparable to those of the general population after the first four months. Pre-pregnancy smoking is associated with higher rates of CTR during pregnancy and the first year following delivery.
Our study highlights the need for additional research to further investigate pelvic fractures and their treatment during pregnancy as well as their potential effects on the developing foetus. This includes exploring the increased incidence of pelvic fractures during the first months after delivery observed in this study. Furthermore, further studies are required to examine the impact of TOP on fracture risk during the postpartum year. Additionally, it would be worthwhile to investigate the increased risk of reoperation during the postpartum year following lumbar discectomy as well as the decreasing rate of CTR leading up to delivery.
9 ACKNOWLEDGEMENTS

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10 REFERENCES


and Rehabilitation, 99(4), 766–775.
https://doi.org/10.1016/j.apmr.2017.08.484

https://doi.org/10.1016/J.JCOT.2020.07.001


https://doi.org/10.1097/TA.0b013e3181589fa4


https://doi.org/10.1152/physrev.00001.2012


British Orthopaedic Association Audit Standards for Trauma. (2018). *The Management of Patients with Pelvic Fractures.* https://www.boa.ac.uk/static/e0ff512b-6364-42ef-af23617e1894d8bd/04fe5a18-47a2-46d7-9aa6cc158825014d/the management of patients with pelvic fractures.pdf

tunnel syndrome in primary care. *Clinical Epidemiology, 10*, 739–748. https://doi.org/10.2147/CLEP.S154409


review. *Injury, 37*(8). https://doi.org/10.1016/J.INJURY.2006.04.130


Musculoskeletal Disorders


932–937. https://doi.org/10.1097/00005373-198610000-00013


https://doi.org/10.1016/j.knee.2008.09.005


Martínez-Perez, A., Fahandezh-Saddi Díaz, H., Martínez-Martín, J., 14 International Journal of Behavioral Nutrition and Physical Activity

Sedentary behaviours during pregnancy: a systematic review.


Bone and Mineral Research

Adults Aged 18 to 49 Years: A Population-Based Study.

200103010-00007

https://doi.org/10.1097/00007632-198705000-00011


https://doi.org/10.2106/00004623-199501000-00016


https://www.julkari.fi/handle/10024/137770


https://yhteistyotilat.fi/wiki08/display/JULHI22


Hardy, J., Collin, C., Mathieu, P. A., Vergnenège, G., Charissoux, J. L. &


Kovacs, C. S., Lanske, B., Hunzelman, J. L., Guo, J., Karaplis, A. C. &


https://doi.org/10.1016/s0140-6736(73)90818-0

of bone formation to resorption. *Trends in Molecular Medicine*, 11(2),

*Physical Medicine and Rehabilitation Clinics of North America*, 19(1),

Mathews, J. A., Mills, S. B., Jenkins, V. M., Grimes, S. M., Morkel, M. J.,
Mathews, W., Scott, C. M. & Sittampalam, Y. (1987). Back pain and
sciatica: controlled trials of manipulation, traction, sclerosant and
https://doi.org/10.1093/rheumatology/26.6.416

Matsumoto, E., Yoshimura, K., Nakamura, E., Hachisuga, T. & Kashimura, M.
(2009). The use of opioids in a pregnant woman with lumbar disc


https://doi.org/10.1097/00003086-199608000-00011

Mattila, V. M., Huttunen, T. T., Sillanpää, P., Niemi, S., Pihlajamäki, H. &
radius fractures: a nationwide study between 1998 and 2008 in
https://doi.org/10.1097/TA.0b013e3182231af9

Mattila, V. M., Sillanpää, P., livonen, T., Parkkari, J., Kannus, P. &
ligament injury in the Finnish National Hospital Discharge Register.
Injury, 39(12), 1373–1376. https://doi.org/10.1016/j.injury.2008.05.007


Parreira, P., Maher, C. G., Steffens, D., Hancock, M. J. & Ferreira, M. L.


Peul, W. C., van Houwelingen, H. C., van den Hout, W. B., Brand, R., Eekhof,


Ponkilainen, V. T., Kuitunen, I., Liukkonen, R., Vaajala, M., Reito, A. &


Putnam, J. (1880). A series of cases of paresthesias, mainly of the hand, or periodic recurrence, and possibly of vaso-motor origin. *Archives of Medicine, 4*, 147–162.


https://doi.org/10.1097/01.BRS.0000218072.25964.A9


https://doi.org/10.1359/jbmr.2002.17.6.1051


Vougioukas, V. I., Kyroussis, G., Gläsker, S., Tatagiba, M. & Scheufler, K. M.


pregnancy. *Journal of Orthopaedic Trauma*, 17(8), 582–584. https://doi.org/10.1097/00005131-200309000-00008


Nyrhi Lauri, Kuitunen Ilari, Ponkilainen Ville, Huttunen Tuomas, Mattila Ville

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Incidence of fracture hospitalization and surgery during pregnancy

A retrospective cohort study using nationwide data from the Finnish Care Register for Health Care in Finland—1998–2017: a retrospective register-based cohort study

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Abstract

Introduction

Osteoporosis is common during pregnancy, with transient pregnancy-associated osteoporosis being responsible for a significant proportion of hip fractures. Fractures during pregnancy can cause mortality and adverse short- and long-term outcomes of pregnancy in Finland between 1998 and 2017.

The aim of this study was to assess the incidence of all major fractures and surgery during pregnancy and the outcomes of pregnancy in Finland between 1998 and 2017.

Materials and methods

A retrospective cohort study using nationwide data from the Finnish Care Register for Health Care was performed to identify all pregnant women with hospitalization due to a fracture diagnosis, followed until hospital discharge or pregnancy termination. Trauma, obstetric, and PTB events were defined using administrative registers. The incidence of fracture hospitalization was quantified in pregnant women per 100,000 pregnancy-years.

Results

Of a total 629,911 pregnancies, 1813 pregnant women were hospitalized with a fracture diagnosis, yielding an incidence of 247 fractures/100,000 pregnancy-years. Of these, 24% (n = 513/2098) were treated operatively. The most common fractures were fractures of the tibia, ankle, and the forearm, which made up half of all fractures. The incidence of pelvic fractures was 6.8/100,000 pregnancy-years, with an operation rate of 14%. The stillbirth rate of all fracture patients was low at 0.6% (n = 10/1813), although this was 1.5-fold the overall stillbirth rate in Finland. Lumbosacral and comminuted spinopelvic fractures resulted in preterm delivery in 25% (n = 5/20) of parturients, with a stillbirth rate of 10% (n = 2/20).

Discussion

Fractures during pregnancy are common and have been associated with adverse perinatal outcomes. Maternal mortality and stillbirth rates remain low among women with fractures leading to hospitalization or surgery during pregnancy.

Conclusion

The incidence of fracture hospitalization during pregnancy is lower than in the general population, and fractures in this population are more often treated conservatively. A higher proportion of preterm deliveries and stillbirths occurred in women with lumbosacral and comminuted spinopelvic fractures. Maternal mortality and stillbirth rates remain low among women with fractures leading to hospitalization or surgery during pregnancy.

Pregnancy · Trauma · Fracture · Epidemiology · Incidence

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Abstract

Introduction

Polytrauma, (ISS > 12), or polytrauma with fetal mortality has been evaluated in a small number of pregnant women in their third trimester. Other injuries during pregnancy are collisions between motor vehicles and pedestrians, and falls [9]. Polytrauma, (ISS > 12), or polytrauma with fetal mortality has been evaluated in a small number of pregnant women in their third trimester. Other injuries during pregnancy are collisions between motor vehicles and pedestrians, and falls [9].

Discussion

The maternal and fetal death during pregnancy [1] is Traumatic injury is the leading non-obstetrical cause of mortality in pregnancy, with a known incidence of 5.2/100,000 pregnancies [2]. In addition to increasing maternal and perinatal mortality, trauma has also been reported to increase the risk for preterm birth, cesarean section, preterm labor, and postpartum hemorrhage [1]. The exact incidence of traumatic injuries during pregnancy is not known, but it has been estimated to affect approximately 8% of pregnancies [2].

Discussion

A previous case study showed that traumatic injury of the pelvis or acetabulum during pregnancy can lead to pregnancy termination in 35–60% of cases [6]. In patients with maturity membrane rupture, and placental abruption [3–5]. Polytrauma, (ISS > 12), or polytrauma with fetal mortality has been evaluated in a small number of pregnant women in their third trimester. Other injuries during pregnancy are collisions between motor vehicles and pedestrians, and falls [9]. Polytrauma, (ISS > 12), or polytrauma with fetal mortality has been evaluated in a small number of pregnant women in their third trimester. Other injuries during pregnancy are collisions between motor vehicles and pedestrians, and falls [9].

Conclusion

In conclusion, traumatic injuries during pregnancy are common and have been associated with adverse perinatal outcomes. Maternal mortality and stillbirth rates remain low among women with fractures leading to hospitalization or surgery during pregnancy.

Lauri Nyrhi1,2 • Ilari Kuitunen3,4 • Ville Ponkilainen1 • Tuomas T. Huttunen2,5 • Ville M. Mattila3,6

Abstract

Introduction The aim of this study was to assess the incidence of all major fractures and surgery during pregnancy and the outcomes of pregnancy in Finland between 1998 and 2017.

Materials and methods A retrospective cohort study using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register. As participants we included all women aged between 15 and 49 years from January 1, 1998 to December 31, 2017 and their ≥ 22-week pregnancies.

Results Of a total 629,911 pregnancies, 1813 pregnant women were hospitalized with a fracture diagnosis, yielding an incidence of 247 fractures/100,000 pregnancy-years. Of these, 24% (n = 513/2098) were treated operatively. The most common fractures were fractures of the tibia, ankle, and the forearm, which made up half of all fractures. The incidence of pelvic fractures was 6.8/100,000 pregnancy-years, with an operation rate of 14%. The stillbirth rate of all fracture patients was low at 0.6% (n = 10/1813), although this was 1.5-fold the overall stillbirth rate in Finland. Lumbosacral and comminuted spinopelvic fractures resulted in preterm delivery in 25% (n = 5/20) of parturients, with a stillbirth rate of 10% (n = 2/20).

Conclusion The incidence of fracture hospitalization during pregnancy is lower than in the general population, and fractures and the fetal membrane rupture, and placental abruption [3–5]. A previous case study showed that traumatic injury of the pelvis or acetabulum during pregnancy can lead to pregnancy termination in 35–60% of cases [6]. In patients with polytrauma, (ISS[7] > 12) fetal mortality has been evaluated to be 65% [8]. The most common injury mechanisms during pregnancy are collisions between motor vehicles and pedestrians, and falls [9].

A small number of pregnant women in their third trimester suffer from transient pregnancy-associated osteoporosis,
which has been associated with low-energy spinal column fractures and delivery-related proximal femur fractures [10]. Transient osteoporosis during pregnancy has previously been hypothesized to be underdiagnosed as a cause of back pain during pregnancy [11].

To date, no large-scale epidemiological studies investigating the incidence of fractures leading to hospitalization during pregnancy have been published. However, whole-population incidences of pelvic and acetabular fractures, some of the most critical fractures regarding pregnancy and delivery, have recently been reported to be 73 and 11 per 100,000 person-years, respectively [12]. Moreover, the number of pregnant women treated operatively for pelvic and acetabular fractures has been reported to be 4 times fewer than females in the general population [12]. Operative treatment methods for fractures during pregnancy vary, and even the most invasive locking-plate fixations and intramedullary nails are not excluded during pregnancy [13, 14].

The aim of our study is to analyze all fractures leading to hospitalization among pregnant women and the normal population of fertile-aged women in Finland between 1998 and 2017 to provide exact data on the incidences of fractures leading to hospitalization and subsequent operations. As a secondary outcome, we aim to report the outcome rates of pregnancies influenced by severe trauma.

**Materials and methods**

Data for this nationwide retrospective register-based cohort study were obtained from the Finnish Health and Social Data Permit Authority (FinData). We combined data from the Finnish Care Register for Health Care and the Medical Birth Register. The Finnish Care Register includes hospital inpatient data as well as data from day surgeries and specialized outpatient care. The coverage and accuracy of the registers have been proven to be excellent, although information regarding patient comorbidities is lacking [15–17]. The Medical Birth Register contains information on all pregnancies ending in delivery after gestational week 21 + 6 or fetal weight over 500 g. The validity and coverage of the register are excellent [18].

Our study period was from January 1, 1998 to December 31, 2017. Patients were selected from the Care Register using all fracture diagnoses coded with the 10th version of the International Classification of Diseases, (ICD-10) [19] and all orthopedic fracture procedure codes from the Finnish version of the Nordic Medico-Statistical Committee (NOMESCO) classification (Supplementary file 1) [20]. All female patients aged 15–49 years at the time of the injury, defined as fertile by the World Health Organization, were included in the study [21].

The registers were combined after the individuals were pseudonymized by FinData. The pseudonymization key was retained by FinData and none of the authors had access to the key. Additionally, all files were analyzed by the safe remote-controlled environment provided by FinData. Using information on the date of birth and pregnancy duration from the Medical Birth Register, we were able to isolate incidents that occurred during pregnancy. In our study, the primary outcome was hospitalization with any of the fracture ICD-10 or operation codes. Only the first hospitalization per fracture or operation was taken into account. The formation of the study cohort is described in Fig. 1.

This study has been granted research permission from the Finnish Health and Social Data Permit Authority FinData, permission THL/1756/14.02.00/2020. According to Finnish research legislation and the Finnish National Board on Research Integrity appointed by the Ministry of Education and Culture, a review by a formal ethics committee is not required for the research of public and published data, registry and documentary data, and archive data [22]. Our study was formatted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (Supplementary file 2) [23].

**Statistical analysis**

Yearly incidence rates (per 100,000 pregnancy-years) were calculated for fractures and operations and divided into anatomical subgroups. Total incidences and 95% confidence intervals (CI) were then calculated for these subgroups using an estimated pregnancy length of 39 weeks. For the normal population of women of similar age, age-adjusted incidence rates (per 100,000 person-years) were calculated. Age-adjustment was conducted by first calculating the crude incidence rates for each one-year age-group of the normal population separately. These incidence rates were then weighted...
Results

All fractures

The cumulative 20-year incidence for fractures was 247 per 100,000 pregnancy-years (95% CI 237–259) and 61 per 100,000 pregnancy-years (95% CI 56–67) for fracture surgery. In total, 24% (n = 513/2098) of the fractures underwent operative treatment. Annual incidence rates for fractures varied between 204 and 313 fractures per 100,000 pregnancy-years. Corresponding operation rates varied from 33 to 86 operations per 100,000 pregnancy-years (Fig. 2). For the normal population of women the respective 20-year incidence for all fractures was 554 per 100,000 person-years and 150 per 100,000 person-years for fracture surgery. For the normal population the total age-adjusted fracture incidence was 553 per 100,000 person-years (95% CI 536–572) for a total IRR of 0.34 (95% CI 0.33–0.34). 30% of all fractures were treated operatively in the normal population.

According to Finnish Care Register data, a total of 1813 pregnant women were hospitalized with a fracture diagnosis during the 20-year study period. In this population, a total of 2098 fractures were registered. The mean age (±SD) for all patients was 29.6 (±5.7). In-hospital maternal mortality due to trauma was low, as three mothers died as a result of trauma (incidence 0.2 per 100,000 pregnancies, 95% CI: 0–0.6). In all cases, the main cause of death was severe traumatic brain injury. The stillbirth rate was 0.9 per 100,000 pregnancies (95% CI: 0.4–1.6, 0.5% of fracture patients, n = 10/2098), which is 1.2-fold the stillbirth rate of the general population in Finland [18].

Fig. 2 Yearly incidence (per 100,000 pregnancy-years) of fracture hospitalization and surgery during pregnancy in Finland between 1998 and 2017 and their 95% confidence intervals
**Anatomical distribution of fractures**

The most common anatomical location of fracture was the tibia and ankle (incidence 70.1/100,000) of which distal tibial and fibular fractures of the ankle accounted for 67% (n = 399/595; Table 1). Fractures of the forearm had an incidence rate of 54.9/100,000, and the rate of surgery was 16% (n = 7/666). Fractures of the distal radius accounted for 54% (n = 253/466) of all forearm fractures. The highest rate of surgical treatment was in fractures of the thigh (50%, n = 13/26), followed by fractures of the tibia and ankle (42%, n = 250/595). The incidence of pelvic fractures was 6.8 per 100,000 pregnancy-years (95% CI: 4.0–6.7), and the rate of surgical treatment was 14% (n = 8/59), which was the third lowest rate of surgery after fractures of the skull (0%, n = 0/114) and spine (6%, n = 6/102).

For the normal population, all fracture all locations were more common compared to the pregnant population. Fracture incidence profile by anatomic location in the normal population resembled that of pregnant women with fractures of the tibia and ankle, and forearm being the most common (incidences 150.8 and 120.8 per 100,000 person-years respectively). It was in fractures of the thigh where the largest proportional decrease was seen, where the fracture rate of the normal population was 3.6-fold. The smallest difference was seen in fractures of the pelvis where the fracture rate of the normal population was 1.8-fold compared to the pregnant population.

**Critical and multiple major fractures during pregnancy**

A total of 39 patients had critical fractures concerning pregnancy with an incidence of 4.6/100,000 pregnancy-years (95% CI: 3–6). Rate of surgery was 21% (n = 8/39). All incidences remained markedly lower than in the normal population where the total incidence was 30.5 per 100,000 person-years. The incidence for multiple major fractures of the torso or proximal limbs was 1.6/100,000 pregnancy-years (95% CI: 1–3), and the rate of surgery was 9% (n = 1/11). Preterm delivery occurred in 21% (n = 8/39) and stillbirth in 10% (n = 4/39) of critical fractures. The most common fracture was a lumbar spinal column or sacral fracture (n = 7, incidence 0.8/100,000 pregnancy-years), followed by multiple spinal and pelvic fractures (n = 6, incidence 0.7/100,000 pregnancy-years), other fractures of the pelvis (n = 5, incidence 0.6/100,000 pregnancy-years) and fractures of the femoral neck (n = 4, incidence 0.5/100,000 pregnancy-years). It was specifically in fractures of the lumbar spine, the most common single fracture in pregnant women, the most dramatic decrease was seen with incidences remaining over tenfold smaller when compared to the normal population. Critical fractures resulted in preterm delivery in 14% of cases (n = 10/82). Subtrochanteric fractures (n = 1/2) and femoral shaft fractures (n = 1/2) had a rate of surgery of 50%. Sacral fractures had a rate of surgery of 29% (n = 2/7) and a preterm birth rate of 14% (n = 1/7). The stillbirth rate was 0% (n = 0/11). In cases of multiple pelvic fractures, the rate of surgery was 33% (n = 2/6); the preterm birth rate was 33% (n = 2/6), and the stillbirth rate was 17% (n = 1/6). Most of lumbar spine fractures were mostly treated conservatively (rate of surgery 14%, n = 1/7). These fractures resulted in preterm birth in 29% of cases (n = 2/7), and the stillbirth rate was 14% (n = 1/7). In total, lumbosacral and comminuted spinopelvic fractures resulted in preterm delivery in 25% (n = 5/20) of parturients, with a stillbirth rate of 10% (n = 2/20). Isolated fractures of the acetabulum and pubis were all treated conservatively until delivery, with

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Incidences of fractures and their operations divided by anatomical location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomical location</td>
<td>Pregnant women</td>
</tr>
<tr>
<td></td>
<td>Fractures</td>
</tr>
<tr>
<td>Head</td>
<td>13.44 (11.01–16.13)</td>
</tr>
<tr>
<td>Spine</td>
<td>12.03 (9.8–14.59)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>6.83 (5.29–8.97)</td>
</tr>
<tr>
<td>Brachium</td>
<td>19.56 (16.69–22.67)</td>
</tr>
<tr>
<td>Forearm</td>
<td>54.92 (50.03–60.13)</td>
</tr>
<tr>
<td>Hand</td>
<td>33.23 (29.47–37.35)</td>
</tr>
<tr>
<td>Thigh</td>
<td>3.01 (2.0–4.49)</td>
</tr>
<tr>
<td>Tibia and ankle</td>
<td>70.12 (64.6–75.87)</td>
</tr>
<tr>
<td>Foot</td>
<td>12.37 (10.12–14.49)</td>
</tr>
<tr>
<td>Total</td>
<td>247.24 (236.77–258.05)</td>
</tr>
</tbody>
</table>

Incidences reported as fractures or operations per 100,000 pregnancy-years. Poisson exact test used to calculate 95% confidence intervals in brackets.
no preterm births or stillbirths. The results are presented in more detail in Table 2.

**Discussion**

In our nationwide study, the total incidence of fractures leading to hospitalization during pregnancy in the Finnish general population was 247 fractures per 100,000 pregnancy-years between 1998 and 2017. Approximately one quarter of these fractures required operative treatment, yielding a cumulative incidence of 61 operations per 100,000 pregnancy-years. With a Finnish population of 5.5 million, this amounts to a mean 27 operations yearly nationwide. During the study period, the yearly incidences of fractures and operations remained steady. Moreover, fractures of the tibia, ankle, and forearm made up half of all fractures and 65% of all operations. All fracture rates remained markedly lower than the age-adjusted female normal population. Maternal in-hospital mortality was low.

As previous nationwide studies on the incidence of fractures and fracture surgery on expectant mothers are non-existent, we are unable to compare our results to the findings of earlier studies. However, overall fracture epidemiology has been largely studied and trauma has been estimated to complicate one in 12 pregnancies [24]. Court-Brown et al. in Scotland in 2000 and Bergh et al. in Sweden between 2015 and 2018 reported whole-population fracture incidences for women of 1065 and 1413/100,000 person-years, respectively, incorporating both emergency department visits and hospitalizations [25, 26]. While these incidence figures are not necessarily comparable, all studies demonstrated that female fracture incidence remained fairly steady until onset of menopause, after which incidence started to grow rapidly.

In all the studied categories, our fracture incidence remained lower than the fracture incidence in the general population [12, 25, 27–29]. Fractures follow a different age distribution for men and women. For men, the distribution resembles a parabola with bias in the younger and older populations. In women, however, the incidence of fractures remains steady until a rapid increase occurs after menopause [25, 26]. This is due to the increase of osteoporotic fractures in the older population, which is exacerbated by bone demineralization in postmenopausal women [30]. The low total incidence of fractures in our study could in part be explained by our decision to include only pregnant women aged 15–49, and thereby excluded most osteoporotic fractures from the study. Lower incidences of hospitalized fractures can also be partly explained by the lower risk-taking behavior among pregnant women. This could be supported by the fact that the most dramatic decrease in incidence was seen in fractures of the thigh, which in the working population are traditionally high-energy fractures [31]. Furthermore, expectant women are often relieved from physically and mentally fatiguing work during early pregnancy and completely from all work during the third trimester, thus possibly making them less susceptible to work-related trauma. Pregnant women are advised against physical activity involving body contact or sudden movements and have been shown to spend more than half their time in a sedentary position [32, 33]. As a possible contributing factor, pregnant women are also encouraged to abstain from alcohol, with alcohol intoxication having been previously defined as a risk factor for traumatic events [34]. Lower incidence figures of hospitalized fractures also partially question the clinical importance of

**Table 2** Incidences per 100,000 pregnancy-years of major fractures of the spinopelvic area divided by anatomical location (ICD-10 code) and multiple major fractures of the torso

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Count</th>
<th>Incidence (95% CI, surgical treatment %)</th>
<th>Preterm delivery (%)</th>
<th>Stillbirth (%)</th>
<th>Norma population incidence (95% CI, surgical treatment %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of lumbar vertebra ($S32.0$)</td>
<td>7</td>
<td>0.83 (0.33–1.69, 14%)</td>
<td>29</td>
<td>14</td>
<td>10.49 (8.17–13.26, 9%)</td>
</tr>
<tr>
<td>Fracture of sacrum ($S32.1$)</td>
<td>7</td>
<td>0.83 (0.33–1.69, 29%)</td>
<td>14</td>
<td>0</td>
<td>2.86 (1.73–4.46, 7%)</td>
</tr>
<tr>
<td>Fracture of acetabulum, pubis and ilium ($S32.3, S32.4, S32.5$)</td>
<td>6</td>
<td>0.71 (0.25–1.53, 0%)</td>
<td>0</td>
<td>0</td>
<td>4.67 (2.37–8.45, 10%)</td>
</tr>
<tr>
<td>Multiple fractures of lumbar spine and pelvis ($S32.7$)</td>
<td>6</td>
<td>0.71 (0.25–1.53, 33%)</td>
<td>33</td>
<td>17</td>
<td>2.78 (1.67–4.44, 20%)</td>
</tr>
<tr>
<td>Fracture of other parts of pelvis ($S32.8$)</td>
<td>5</td>
<td>0.59 (0.19–1.37, 0%)</td>
<td>0</td>
<td>0</td>
<td>2.12 (1.17–3.54, 5%)</td>
</tr>
<tr>
<td>Fracture of neck of femur ($S72.0$)</td>
<td>4</td>
<td>0.47 (0.13–1.12, 25%)</td>
<td>25</td>
<td>0</td>
<td>2.78 (1.67–4.36, 29%)</td>
</tr>
<tr>
<td>Per-, and subtrochanteric femur fractures and femoral shaft fractures ($S72.1, S72.2, S72.3$)</td>
<td>4</td>
<td>0.47 (0.13–1.12, 50%)</td>
<td>50</td>
<td>0</td>
<td>4.82 (2.6–8.52, 32%)</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>4.6 (3.27–6.28, 21%)</td>
<td>21</td>
<td>10</td>
<td>30.52 (26.47–35.03, 16%)</td>
</tr>
<tr>
<td>Multiple major orthopedic fractures</td>
<td>14</td>
<td>1.65 (0.91–2.77, 7%)</td>
<td>14</td>
<td>7</td>
<td>24.27 (20.66–28.33, 36%)</td>
</tr>
</tbody>
</table>

Poisson exact-test was used to calculate 95% confidence intervals for incidences in brackets. Rates of surgical treatment, preterm delivery, and fetal mortality are shown as a percentage of the total count.
transient pregnancy-induced osteoporosis-related fractures during pregnancy. Transient osteoporosis has been shown to recover slowly after delivery, and these fractures occur and are mostly diagnosed post-partum after radiological and behavioral restrictions have been lifted [35–39].

Surgical rates were in line with previously defined whole-population values [12, 25, 27–29]. However, surgical rates for pelvic fractures were lower both when compared to the normal population in our study and previously defined figures for high-energy pelvic fractures, which have previously been shown to be predominant in the young [40, 41]. This finding suggests that surgeons are more cautious about operating on pelvic fractures in pregnant women when compared to the normal population. Pelvic fractures have been associated with adverse fetal and maternal outcomes, and a previous study by Weiss et al. defined the rate of fetal death due to maternal trauma at 3.7/100,000 live births [5, 42]. While the stillbirth rate of 0.9/100,000 pregnancies (0.6%) for all fractures falls below previously defined figures, the stillbirth rate of 10% for comminuted spinopelvic and lumbosacral fractures remains relatively high.

The main strength of our study is the excellent national coverage of hospitalized fractures. Combined with the excellent national coverage of the Birth Register, we were able to create unique national data on hospitalized fractures during pregnancy and the subsequent delivery outcomes [15–17]. Thus, our results are provided good external validity. A secondary strength of our study is the long follow-up time (20 years). As a potential limitation, the Finnish national Birth Register only includes the outcomes of pregnancies with a viable fetus (≥22 weeks). Hence, fractures with termination of pregnancy before 22 full weeks were not included in our study. However, in pregnancies <22 weeks, the fetus is enclosed in the womb and surrounded by soft tissue, where it is more protected. A second limitation of the study is that the Care Register only includes hospitalized fractures. Non-operatively treated minor fractures in Finland, such as fractures of the extremities, are primarily treated in a primary health care setting and are therefore not accurately registered in the Care Register. As a third limitation, we were only able to look at 39 critical fractures relating to pregnancy. This is attributed to the rare nature if these fractures when considering our long follow-up time and national coverage.

Conclusion

Our results suggest that fractures during pregnancy occur more seldom than in the general fertile-aged female population, while their incidence has remained stable during the past 20 years. Interestingly, our results show that surgical rates remain lower than in the general female population, with especially lumbosacral and comminuted pelvic fractures having higher rates for preterm delivery. Despite this, maternal and fetal outcomes remained good. Operation rates varied on a yearly basis, suggesting that pregnant women with fractures are indeed dealt with delicately. We hope our results will serve as a basis for future studies and provide important epidemiological benchmark results of fractures during pregnancy.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00402-023-04931-w.

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Declarations

Conflict of interest None were declared.

Ethical approval Not applicable.

Informed consent Not applicable.

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References


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Incidence of Fracture Hospitalization and Surgery in Women Increases Steadily During the Puerperal and Lactation Period: A Retrospective Register-Based Cohort Study in Finland From 1999 to 2018

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low rates in the working population. In women, a stable rate with example, fractures in men resemble a bimodal parabolic trend example, fractures in men resemble a bimodal parabolic trend

Introduction

Women suffer more fractures than men. This is especially women suffer more fractures than men. This is especially

and Mineral Research (ASBMR).

The incidence of fracture hospitalization after delivery increased steadily during the puerperal and the lactation periods but remained lower than in the general population (age-adjusted incidence 554/100,000 person-years at 4 months after delivery, with an operation rate of 22%. Over half of all fractures occurred between 4 and 12 months after delivery (mean 6.6 months). The incidence of fracture hospitalization after delivery increased steadily during the year after delivery. Altogether, 29% (n = 904/3140) of these fractures were treated operatively. The most common fractures were ankle fractures of the hands and feet, but low incidences of traditional osteoporotic fractures. Moreover, men are also greatly overrepresented in this age group compared to women.

Epidemiological patterns, depending on age and sex. For young adults aged 18 to 49 years, apparent in older populations, where low-energy osteoporotic fractures rise in incidence. In young adults aged 18 to 49 years, apparent in older populations, where low-energy osteoporotic fractures rise in incidence. Moreover, men are also greatly overrepresented in this age group compared to women.

Most common mechanisms being falls from height and motor vehicle collisions. Interestingly, when compared to adults >50 years, young adults present relatively high incidences of fractures of the hands and feet, but low incidences of traditional osteoporotic fractures. Moreover, men are also greatly overrepresented in this age group compared to women.

Most common mechanisms being falls from height and motor vehicle collisions. Interestingly, when compared to adults >50 years, young adults present relatively high incidences of fractures of the hands and feet, but low incidences of traditional osteoporotic fractures. Moreover, men are also greatly overrepresented in this age group compared to women.

This retrospective cohort study assesses the incidences of major fractures and surgery in women during the puerperium and the lactation period in Finland between January 1, 1999, and December 31, 2018. Using nationwide data from the Finnish Care Register for Health Services, the incidence of fractures after delivery was evaluated.

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Additional Supporting Information may be found in the online version of this article.

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Incidence of Fracture Hospitalization and Surgery in Women Increases Steadily During the Puerperal and Lactation Period: A Retrospective Register-Based Cohort Study in Finland From 1999 to 2018

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ABSTRACT
This retrospective cohort study assesses the incidences of major fractures and surgery in women during the puerperium and the lactation period in Finland between January 1, 1999, and December 31, 2018. Using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register, all women aged between 15 and 49 years with a fracture hospitalization within 12 months of delivery between 1999 and 2018 were included. During the study period, a total of 3140 fractures after delivery and 152,800 fractures of the female normal population of similar age were hospitalized. The incidence rate after delivery increased from 219/100,000 person-years at 4 months to 310 fractures/100,000 person-years during the latter 8 months of the first year after delivery. Altogether, 29% (n = 904/3140) of these fractures were treated operatively. The most common fractures were ankle and distal radius fractures, which made up one-third of all fractures. The incidence of pelvic fracture hospitalization was 15/100,000 person-years at 4 months after delivery, with an operation rate of 22%. Over half of all fractures occurred between 6 and 12 months after delivery (mean 6.6 months). The incidence of fracture hospitalization after delivery increased steadily during the puerperium and the lactation periods but remained lower than in the general population (age-adjusted incidence 554/100,000 person-years) with an incidence rate ratio of 0.51. However, a higher proportion of pelvic fractures were observed in the first months after delivery. Surgical rates were in line with the general population. Fractures of the wrist and ankle made up most of the fractures. © 2022 The Authors. Journal of Bone and Mineral Research published by Wiley Periodicals LLC on behalf of American Society for Bone and Mineral Research (ASBMR).

KEY WORDS: INCIDENCE; PUERPERIUM; LACTATION; FRACTURES; SURGERY

Introduction
Fracture incidence has long been known to follow different epidemiological patterns, depending on age and sex. For example, fractures in men resemble a bimodal parabolic trend with high rates in children, adolescents, and older adults and low rates in the working population. In women, a stable rate with a rapid increase after menopause is observed.(1,2) Overall, women suffer more fractures than men. This is especially apparent in older populations, where low-energy osteoporotic fractures rise in incidence.(3) In young adults aged 18 to 49 years, 80% of fractures are the result of high-energy trauma, with the most common mechanisms being falls from height and motor vehicle collisions. Interestingly, when compared to adults >50 years, young adults present relatively high incidences of fractures of the hands and feet, but low incidences of traditional osteoporotic fractures. Moreover, men are also greatly overrepresented in this age group compared to women.(4)
Pregnancy and lactation are known stress factors for calcium metabolism in women. Despite little change in nutrition, a small number of women develop transient osteoporosis of pregnancy (TOP) in the third trimester of pregnancy.\(^\text{19}\) Case reports have previously been published describing late-pregnancy, delivery-related, and lactation period osteoporotic fractures.\(^\text{6-8}\) Although a high proportion of mothers express lower than normal vitamin D and estrogen levels, the pathophysiology behind TOP is not yet fully understood.\(^\text{9,10}\) Although radiological findings normalize within a few weeks of delivery, the effects of pregnancy and lactation on calcium metabolism normalize only slowly after normal menstruation has resumed and lactation has ended.\(^\text{5,9}\)

A recent population-based cohort study from Finland showed that the fracture incidence in pregnant women was smaller than in the general population.\(^\text{11}\) However, considering the late onset and lasting effects of TOP during pregnancy and lactation, we hypothesized that mothers suffer more fractures during their puerperal and lactation period than women in the general population. In this study, we analyzed all major fractures leading to hospitalization among mothers during their puerperal and lactation period and the normal population in Finland between 1999 and 2018 to provide information on the incidence rates of such fractures.

### Materials and Methods

Data for this nationwide retrospective register-based cohort study were obtained from the Finnish Health and Social Data Permit Authority (FinData).\(^\text{12}\) We combined data from the Finnish Care Register for Health Care and the Medical Birth Register. The Finnish Care Register includes hospital inpatient data as well as data from day surgeries and specialized outpatient care containing both hospital clinic and emergency room visits. The coverage and accuracy of the register regarding diagnoses and discharges has been proven to be excellent, although information regarding patient comorbidities is lacking.\(^\text{13-15}\) The Medical Birth Register contains information on all pregnancies ending in delivery after gestational week 21 + 6 or fetal weight >500 g. The validity and coverage of the register is excellent and has been estimated to cover 100% of newborns in Finland.\(^\text{16}\)

Our study period was from January 1, 1999, to December 31, 2018. Patients were selected from the Care Register using all fracture diagnoses coded with the 10th Finnish version of the International Classification of Diseases (ICD-10)\(^\text{17}\) and all orthopedic fracture surgery codes from the Finnish version of the Nordic Medico-Statistical Committee (NOMESCO) classification (Appendix S1).\(^\text{18}\) All female patients aged 15 to 49 years at the time of the injury, defined as fertile by the World Health Organization (WHO), were included in the study.\(^\text{19}\)

The registers were combined after the individuals were pseudonymized by FinData. The pseudonymization key was retained by FinData and none of the authors had access to the key. Additionally, all files were analyzed in the safe, remote-controlled environment provided by FinData. Using information on date of birth and pregnancy duration from the Medical Birth Register, we were able to isolate incidents that occurred prior to or during pregnancy. In this study, the primary outcome was hospitalization with any of the fracture ICD-10 or operation codes. Only the first hospitalization period per fracture was considered. The formation of the study cohort is described in Fig. 1.

This study was granted research permission from the Finnish Health and Social Data Permit Authority FinData, permission THL/1756/14.02.00/2020. According to Finnish research legislation and the Finnish National Board on Research Integrity appointed by the Ministry of Education and Culture, a review by a formal ethics committee is not required for the research of public and published data, registry and documentary data, and archive data.\(^\text{20}\) Our study was formatted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (Appendix S2).\(^\text{21}\)

### Statistical analysis

Yearly incidence rates (per 100,000 person-years) were calculated for fracture hospitalization and fracture surgery. Separate calculations were made for follow-up times of 4 and 12 months after delivery. This decision was based on the recommendation from the Finnish Institute for Health and Welfare that exclusive breastfeeding should be for a minimum of 4 months and complementary breastfeeding should be for up to 12 months.\(^\text{22}\) The Finnish recommendation differs from that of the WHO, as the WHO recommendation is for 6 months of exclusive breastfeeding and for the continuation of breastfeeding with complimentary nutrition up to 2 years of age.\(^\text{23}\) For the normal population of women of similar age, age-adjusted incidence rates were calculated. Age-adjustment was conducted by first calculating the crude incidence rates for each 1-year age-group of the normal population separately. These incidence rates were then weighted by multiplying the crude rate by the proportion of women in each age-group of the postpartum population. These weighted rates were then summed to yield the final age-standardized incidence rate. Incidence rate ratios (IRRs) and 95% confidence intervals (CIs) were calculated for incidence rates using Poisson regression. Regarding fracture onset, a Kaplan-Meier survival analysis was performed for fracture patients to visualize the timing of the fracture relative to the number of months after delivery. Fractures were divided into anatomical subgroups and total incidences with 95% CIs were then calculated for the subgroups. All CIs were calculated using the Poisson Exact test. Fractures of the spinopelvic area and sites of traditional osteoporotic fractures were studied separately. For spinopelvic and osteoporotic fractures, we included the codes S22.0 (thoracic spine fracture), S32.0 (lumbar spine fracture), S32.1 (sacral fracture), S32.2 (coccyeal fracture), S32.3 (iliac fracture), S32.4 (acetabular fracture), S32.5 (pubic fracture), S32.7 (multiple pelvic or lumbar vertebrae fractures), S32.8 (other pelvic fracture), S33.4 (traumatic rupture of symphysis pubis), S72.0 (femoral neck fracture), S72.1 (pertochanteric femoral fracture), S72.2 (subtrochanteric femoral fracture), S72.3 (femoral shaft fracture), S42.2 (proximal humeral fracture), and S52.5 (distal radius fracture). Fracture incidences with 95% CIs and operation percentages were calculated for these fractures. Fractures were considered surgically treated if fracture surgery was performed within 14 days of the first hospitalization. Patients with simultaneous multiple pelvic fractures were analyzed with code S32.7 regardless of primary coding. Statistical analyses were performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria; https://www.r-project.org/).

### Results

All fractures

In our 20-year study period, 2689 women were hospitalized with one or more fracture diagnoses during the first 12 months after
delivery. In this population, a total of 3140 fractures were registered. The mean age ± standard deviation (SD) for all patients in postpartum women was 30 ± 5.7 years. For the normal population mean age was 33 ± 10.8 years. The 20-year incidence rate for fracture hospitalization was 280/100,000 person-years (95% CI, 270 to 290) and 87/100,000 person-years for fracture surgery (95% CI, 61 to 71). The total incidence of fracture hospitalization during the first 4 months after delivery was 220/100,000 person-years (95% CI, 205 to 235), rising to 310/100,000 person-years during the next 8 months (95% CI, 297 to 323). In total, 29% of all fractures (n = 904/3140) required operative treatment. Annual incidence rates varied from 205 to 381/100,000 person-years for fracture hospitalization and from 67 to 235/100,000 person-years for fracture surgery (Fig. 2). For the normal population of women the respective 20-year incidence for all fractures was 554 per 100,000 person-years and 150 per 100,000 person-years for fracture surgery. Women during their puerperal and lactation period suffered less fractures than the normal population with a total IRR of 0.51 (95% CI, 0.42 to 0.45; Table 1). 30% of all fractures were treated operatively in the normal population.

The temporal occurrence of fractures within our 12-month follow-up period after delivery was fairly steady, with the mean onset of fractures occurring at 6.6 months after delivery. The incidence of fracture hospitalization showed an increase in the immediate postpartum period, before stabilizing and slowly increasing toward the end of our 12-month follow-up period. (Fig. 3).

Anatomical distribution of fractures

During the first 4 months following delivery, the most common anatomical fracture location was the forearm (incidence 56/100,000 person-years; Table 2) followed by the tibia and ankle (incidence 55/100,000 person-years) and the hand (incidence 29/100,000 person-years). Fractures of the distal radius accounted for 60% of forearm fractures (n = 125/210) and fractures of the distal tibia accounted for 64% of fibula tibia and ankle (n = 218/343) fractures. The incidence of pelvic fracture hospitalization was 15/100,000 person-years, and the rate of surgical treatment was 22%.

Compared to fracture incidence at 4 months after delivery, 12-month incidences increased in all anatomical locations, with fractures of the pelvis being the only group displaying higher fracture incidences during the first 4 months after delivery. Pelvic fracture hospitalization incidence reduced to a 12-month incidence rate of 9/100,000 person-years (95% CI, 7 to 12). The incidence of fracture surgery increased from 65/100,000 person-years to 88/100,000 person-years. Although the incidence of fracture surgery increased for most anatomical fracture locations, incidence decreased for fracture surgery of the head, spine, and pelvis.

For the normal population all fracture locations were more common compared to the postpartum population except for fractures of the pelvis, where fracture incidence (13/100,000 person-years; 95% CI, 10 to 16) was similar to that during the first 4 months after delivery. The most common fracture sites were the tibia and ankle (incidence 151/100,000 person-years) and the forearm (incidence 121/100,000 person-years). The largest difference in incidence was seen in fractures of the thigh where the incidence of the normal population was 2.6-fold when compared to postpartum women (incidence 11/100,000 person-years; 95% CI, 9 to 14). Incidence of fracture surgery was also higher in the normal population in all fractures, but for those of the pelvis where incidences were similar both between the 4

Fig. 1. Flowchart of study cohort formation.
The incidence of fractures during the puerperal and lactation period in Finland between 1999 and 2018 was 76/100,000 person-years (95% CI, 71 to 81) (Table 3).

The overall surgical rate was comparable to that of the normal population (30%; incidence 36/100,000 person-years; 95% CI, 25 to 55). Most fractures displayed a slight increase in incidence from the first 4 months to the latter 8 months. The most significant increase in incidence was observed during the latter 8 months of the first year after delivery (1/100,000 person-years; 95% CI, 2 to 6), the last 8 months of the first year after delivery (1/100,000 person-years; 95% CI, 1 to 2) and the normal population (2/100,000 person-years; 95% CI, 1 to 3).

Spinopelvic and typical osteoporotic fractures after pregnancy

A total of 852 spinopelvic and typical osteoporotic fractures were observed during the first 12 months after pregnancy with a total incidence of 76/100,000 person-years (95% CI, 71 to 81) (Table 3).

The 41% increase in incidence from 4 months to 12 months after delivery previously observed in total fracture hospitalization was not observed here, because the incidence in the first 4 months after delivery was 69/100,000 person-years (95% CI, 61 to 78; n = 257), rising 16% during the latter 8 months to 80/100,000 person-years (95% CI, 73 to 86). Incidence rates of fractures still remained below those of the normal population of 127/100,000 person-years (95% CI, 104 to 159). The incidence of fracture surgery after delivery remained similar from 17/100,000 person-years at 4 months (95% CI, 13 to 22; 25%) to 21/100,000 person-years at 12 months (95% CI, 17 to 24; 26%).

### Table 1. IRRs of Fractures and Fracture Surgery of Postpartum Women and the Normal Population During the First Year After Delivery

<table>
<thead>
<tr>
<th>Time period</th>
<th>Fracture IRR (95% CI)</th>
<th>Fracture surgery IRR (95% CI)</th>
<th>Fracture incidence postpartum (95% CI)</th>
<th>Fracture surgery incidence postpartum (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 12 months after delivery</td>
<td>0.51 (0.51–0.51)</td>
<td>0.5 (0.50–0.50)</td>
<td>279.7 (270.0–289.68)</td>
<td>87.47 (82.09–93.12)</td>
</tr>
<tr>
<td>0 to 4 months after delivery</td>
<td>0.4 (0.38–0.41)</td>
<td>0.4 (0.38–0.46)</td>
<td>219.66 (204.9–235.21)</td>
<td>65.47 (57.53–74.2)</td>
</tr>
<tr>
<td>4 to 12 months after delivery</td>
<td>0.56 (0.56–0.57)</td>
<td>0.55 (0.54–0.56)</td>
<td>309.72 (297.24–322.59)</td>
<td>87.92 (81.33–94.9)</td>
</tr>
</tbody>
</table>

Poisson exact test was used to calculate the IRRs, incidences, and their respective 95% confidence intervals.

IRR = incidence rate ratio.
The overall surgical rate was comparable to that of the normal population (30%; incidence 36/100,000 person-years; 95% CI, 25 to 55). Most fractures displayed a slight increase in incidence from the first 4 months to the latter 8 months. The most significant increase was seen in traditional osteoporotic fracture locations: the thoracic spine, the distal radius, the proximal

### Table 2. Incidences of Fractures and Fracture Surgery During the First 4 and the Latter 8 Months of the First Year After Delivery Divided by Anatomical Location

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Postpartum women</th>
<th>Normal population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0–4 months after delivery</td>
<td>4–12 months after delivery</td>
</tr>
<tr>
<td>Head</td>
<td>11.22 (8.09–15.17)</td>
<td>21.11 (17.95–24.67)</td>
</tr>
<tr>
<td>Spine</td>
<td>12.56 (9.23–16.7)</td>
<td>15.23 (12.56–18.3)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>14.7 (11.07–19.13)</td>
<td>9.22 (7.17–11.67)</td>
</tr>
<tr>
<td>Brachium</td>
<td>18.44 (14.35–23.34)</td>
<td>26.46 (22.9–30.41)</td>
</tr>
<tr>
<td>Forearm</td>
<td>56.39 (49.03–64.53)</td>
<td>78.3 (72.09–84.9)</td>
</tr>
<tr>
<td>Hand</td>
<td>28.86 (23.68–34.84)</td>
<td>46.36 (41.61–51.51)</td>
</tr>
<tr>
<td>Thigh</td>
<td>4.01 (2.24–6.61)</td>
<td>4.14 (2.81–5.88)</td>
</tr>
<tr>
<td>Tibia and ankle</td>
<td>54.78 (47.54–62.82)</td>
<td>75.36 (69.27–81.84)</td>
</tr>
<tr>
<td>Foot</td>
<td>12.03 (8.77–16.09)</td>
<td>21.91 (18.69–25.54)</td>
</tr>
<tr>
<td>Total</td>
<td>219.66 (204.9–235.21)</td>
<td>309.72 (297.24–322.59)</td>
</tr>
</tbody>
</table>

Incidences reported as fractures or operations per 100,000 person-years. Poisson exact-test was used to calculate the 95% confidence intervals in brackets.

Fig. 3. Temporal occurrence of fractures after pregnancy visualized in a Kaplan-Meier survival graph.
Table 3. Incidences of Fractures and Fracture Surgery and Surgical Rates of Spinopelvic and Typical Osteoporotic Fractures During the First 4 and the Latter 8 Months of the First Year After Delivery

<table>
<thead>
<tr>
<th>Anatomical location</th>
<th>Postpartum women</th>
<th>Normal population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0–4 months after delivery</td>
<td>4–12 months after delivery</td>
</tr>
<tr>
<td></td>
<td>Fracture incidence (95% CI)</td>
<td>Fracture surgery incidence (95% CI, surgical rate)</td>
</tr>
<tr>
<td>Fracture of thoracic spine</td>
<td>2.14 (0.92–4.21)</td>
<td>0.27 (0.01–1.49, 12%)</td>
</tr>
<tr>
<td>Fracture of lumbar spine</td>
<td>5.88 (3.68–8.9)</td>
<td>1.6 (0.59–3.49, 27%)</td>
</tr>
<tr>
<td>Fracture of coccyx</td>
<td>3.74 (2.05–6.28)</td>
<td>0 (0–0.99, 0%)</td>
</tr>
<tr>
<td>Fracture of proximal humerus</td>
<td>6.41 (4.11–9.54)</td>
<td>1.34 (0.43–3.12, 21%)</td>
</tr>
<tr>
<td>Fracture of distal radius</td>
<td>33.67 (28.05–40.09)</td>
<td>7.22 (4.75–10.21, 21%)</td>
</tr>
<tr>
<td>Fracture of neck of the femur</td>
<td>1.6 (0.59–3.49)</td>
<td>1.07 (0.39–3.2, 100%)</td>
</tr>
<tr>
<td>Petrochanteric fracture</td>
<td>0.27 (0.01–1.14)</td>
<td>0.27 (0.01–1.49, 100%)</td>
</tr>
<tr>
<td>Subtrochanteric fracture</td>
<td>0.27 (0.01–1.14)</td>
<td>0 (0–0.99, 0%)</td>
</tr>
<tr>
<td>Fracture of femoral shaft</td>
<td>1.07 (0.29–2.74)</td>
<td>0.8 (0.17–2.34, 75%)</td>
</tr>
<tr>
<td>Fracture of sacrum</td>
<td>2.14 (0.92–4.21)</td>
<td>0.27 (0.01–1.49, 12%)</td>
</tr>
<tr>
<td>Fracture of ilium</td>
<td>0.27 (0.01–1.14)</td>
<td>0.53 (0.09–0.99)</td>
</tr>
<tr>
<td>Fracture of acetabulum</td>
<td>1.87 (0.75–3.85)</td>
<td>1.07 (0.29–2.74, 57%)</td>
</tr>
<tr>
<td>Fracture of pubis</td>
<td>1.6 (0.59–3.49)</td>
<td>0.8 (0–0.99, 0%)</td>
</tr>
<tr>
<td>Other fracture of pelvis</td>
<td>1.6 (0.59–3.49)</td>
<td>0.53 (0.06–1.93, 33%)</td>
</tr>
<tr>
<td>Traumatic fracture of symphysis pubis</td>
<td>2.94 (1.47–5.26)</td>
<td>0.61 (0.59–3.49, 55%)</td>
</tr>
<tr>
<td>Multiple pelvic fractures</td>
<td>3.21 (1.66–5.6)</td>
<td>0.27 (0.01–1.49, 8%)</td>
</tr>
<tr>
<td>Total</td>
<td>68.68</td>
<td>16.84</td>
</tr>
<tr>
<td>(60.54–77.61)</td>
<td>(12.94–21.54, 25%)</td>
<td>(73.24–86.15)</td>
</tr>
</tbody>
</table>

Poison exact test was used to calculate 95% confidence intervals for the incidences in parentheses. Rates of surgical treatment are shown as a percentage of the total count.

humerus, and the proximal femur, but incidence rates still remained below those of the normal population. The incidence of fracture hospitalization due to the thoracic spine increased from 2.1/100,000 person-years (95% CI, 0.9 to 4.2) to 3.6/100,000 person-years (95% CI, 2.4 to 5.3). For fracture hospitalization of the proximal humerus and distal radius, the incidence increased from 6.4/100,000 person-years (95% CI, 4.1 to 9.5) to 10/100,000 person-years (95% CI, 8.1 to 13) and from 33/100,000 person-years (95% CI, 28 to 40) to 45/100,000 person-years (95% CI, 41 to 51), respectively. For multiple spinopelvic and comminuted fractures, the incidence rate at 4 months after delivery was higher at 3.2/100,000 person-years (95% CI, 1.7 to 5.6). The incidence rate subsequently declined to 2.5/100,000 person-years at 12 months after delivery (95% CI, 1.5 to 4.0), being the only fracture with higher incidence during the first 4 months after delivery compared to that of the normal population. For these fractures, however, the incidence of fracture surgery increased from 0.3 (95% CI, 0.0 to 1.5, 8%) at 4 months to...
1.1 (95% CI, 0.5 to 2.1, 42%) at 12 months. All traumatic fractures of the symphysis pubis occurred during the first 4 months after delivery (n = 11/11) with an incidence of 2.9/100,000 person-years (95% CI, 1.5 to 5.3), a surgical rate of 55% (n = 6/11), and mean fracture onset of 34 ± 42 days after delivery. Further, all traumatic fractures of the symphysis pubis occurred after vaginal delivery.

Discussion

In our nationwide study, the incidence of most fractures during the first 12 months after delivery remained lower than in the normal population with a total incidence rate ratio of 0.51. Indeed, only the incidences of pelvic fractures during the first 4 months after delivery were similar to those in the general female population of the same age as also reported in previous studies. We also found the total incidence of fractures leading to hospitalization during the first 12 months after delivery to be 280 fractures/100,000 person-years. Of these, one-fourth of the fractures required operative treatment. The incidence of fracture hospitalization increased after the first 4 months after delivery, rising from 220/100,000 person-years during the first 4 months after delivery to 310/100,000 person-years during the latter 8 months. The most common fractures occurred in the distal radius and the ankle, which made up almost one-third of all fractures. Moreover, nearly half of all surgically treated fractures were fractures of the tibia or ankle. Indeed, in the first 4 months after delivery, only pelvic fractures were more common, with traumatic ruptures of the symphysis pubis being distinctive to the puerperal period.

No data regarding the incidence of fractures during the puerperium and lactation periods have previously been published, and therefore we are unable to compare our figures to previously published ones. Farr and colleagues have previously reported the total fracture incidence of women aged 18 to 49 years in Minnesota, USA, to be 1135/100,000 person-years, including both inpatient and outpatient data. Similar whole-population settings have reported the whole-population fracture incidences of women to be 1065 and 1413 fractures/100,000 person-years. Our fracture incidence values for the general population fall behind, but separate values for fractures are in line with previously reported values for the corresponding age group.

In a previous study, 25% of all fractures in women aged 18 to 49 years concerned fractures of the foot, whereas our study showed a major representation of ankle, distal radius, and proximal humerus in both patient groups.

Lower incidences of hospitalized fractures in women during the puerperal and lactation period might be at least partly explained by lower risk-taking behavior. Furthermore, lactating mothers are also encouraged to abstain from alcohol use, which is a known risk factor for traumatic events. Proportionally higher incidences of traditional osteoporotic fractures suggest the possibility of a clinical role for TOP, which is known to only affect a portion of parturients. Our finding that pelvic fractures occurred in higher numbers during the puerperal and lactation period in the first 4 months after delivery support the theory of TOP, which is known to affect the femur, pelvis, and lumbar spine. Fracture surgery for pelvic and spine fractures was also seemingly more common during the first 4 months after delivery, which could support the hypothesis of an osteoporotic etiology. This, together with weight gain, comprising both lean and fatty mass gain, and transient hypocalcemia can lead to a higher susceptibility to trauma during the first months postpartum. In Finland, it is recommended that mothers slowly resume daily activities after 2 months postpartum. This slow return to normal life and employment is in line with our findings of increasing incidences toward 12 months after delivery, and that over half of all fractures occurred between 6 and 12 months after delivery. Together with previous knowledge of transient osteoporotic changes recovering slowly, a part of this increase in incidence could be attributed to the long-term changes effects of lactation and calcium mobilization, together with the increased stress of physical activity after the first months after delivery.

The main strength of our study is the excellent national coverage of hospitalized fractures. Combined with the excellent national coverage of the National Birth Register, we were able to create unique national data on hospitalized fractures during the lactation and puerperal period after delivery, with excellent external validity. A secondary strength of our study is the long follow-up time of 20 years. As a limitation of the study, the Care Register only includes hospitalized fractures. Thus, non-operatively treated minor fractures, such as fractures of the extremities, are primarily treated in a primary health care setting and are therefore possibly missing from the Care Register.

Conclusion

Our results suggest that fracture incidences during the puerperium and lactation period remain lower than in the general population but increase steadily as mothers return to normal life and activities during the first year after delivery. However, pelvic fractures mainly occurred during the first 4 months after delivery, with incidence rates matching those of the general population. Operation rates remained stable and relatively low throughout the study period. We hope our results will provide an epidemiological cornerstone for future studies of fractures and osteoporosis in puerperal and lactating women.

Acknowledgment

Authors’ roles: VM, IK, and TH conceived the study. LN, IK, TH, and VM designed the analysis strategy. LN, IK, and VP formed the cohort and extracted the data. LN performed statistical analysis and wrote the first draft of the manuscript. All other authors revised the manuscript. The corresponding author attests that all listed authors meet the authorship criteria and that no others meeting the criteria have been omitted.

Author Contributions

Lauri Nyrhi: Conceptualization; data curation; formal analysis; investigation; methodology; software; validation; visualization; writing – original draft. Ilari Kuitunen: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; supervision; validation; writing – review and editing. Ville Ponkilainen: Conceptualization; data curation; formal analysis; investigation; methodology; software; visualization; writing – review and editing. Tuomas T. Huttunen: Conceptualization; data curation; investigation; methodology; project administration; supervision; validation; writing – review and editing. Ville M. Mattila: Conceptualization; funding acquisition; investigation; methodology; project administration; resources; supervision; validation; writing – review and editing.
References

Incidence of vaginal birth-related rupture of the pubic symphysis: A nationwide register study in Finland from 1998 to 2018

Nyrhi Lauri, Ponkilainen Ville, Kekki Maiju, Mattila Ville, Kuitunen Ilari

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Radiological intrapubic gap is greater than 1/30,000 pregnancies.2,3 The majority of these ruptures were treated operatively. The incidence of rupture for vaginal delivery was 0.9 per 100,000 deliveries with 95% confidence intervals (CI). We conducted a retrospective nationwide register study in Finland from 1998 to 2018. To assess the incidence of vaginal birth-related rupture of the pubic symphysis, we used the Finnish nationwide health care register data, including nationwide hospital discharges, patients treated in maternity units, and small retrospective cohort studies.1 Using these databases, we aimed to report the incidence of pubic symphysis rupture associated with vaginal delivery and small retrospective cohort studies.1
Incidence of vaginal birth–related rupture of the pubic symphysis: A nationwide register study in Finland from 1998 to 2018

Lauri Nyrhi, Ville Ponkilainen, Maiju Kekki, Ville M. Mattila and Ilari Kuitunen

Abstract

Background and purpose: To assess the incidence of vaginal birth–related rupture of the pubic symphysis in Finland from 1998 to 2018.

Methods: A retrospective cohort study using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register. As participants we included all ≥ 22-week pregnancies of women aged between 15 and 49 years from January 1, 1998 to December 31, 2017. Pubic symphysis rupture was classified based on the ICD-10 code S33.4 and operations were gathered with pelvis-specific operation codes of the Nordic NOMESCO-classification. Incidence per 100 000 deliveries with 95% confidence intervals (CI) was calculated for symphysis rupture and surgery using Poisson’s exact test.

Results: For a total 1 175 326 deliveries, a total of 9 pubic symphysis ruptures occurred during the intrapartum and puerperal periods. All ruptures occurred after vaginal delivery. Of these, 4 ruptures were treated operatively. The incidence of rupture for vaginal delivery was 0.9 per 100 000 deliveries (CI 0.1 to 1.0). No perinatal mortality was observed.

Conclusions: Birth–related ruptures of the pubic symphysis are rate events and are mostly associated with vaginal delivery with most ruptures being treated conservatively.

Keywords

Pregnancy, delivery, symphysis, rupture, epidemiology

Date received: 21 February 2022, accepted: 4 May 2022

Introduction

Rupture of the pubic symphysis is a rare complication of vaginal delivery. Physiological widening during pregnancy is commonly observed, but separation is deemed pathological when the radiological intrapubis gap is greater than 10 mm. Previous studies have reported a wide variation in the incidence of pubic symphysis rupture after vaginal delivery (from 1/300 to 1/30,000 pregnancies). The majority of these studies have been single institute case reports and small retrospective cohort studies. Using nationwide health care register data, we aim to report the incidence of pubic symphysis rupture injuries related to vaginal deliveries.

Methods

We conducted a retrospective nationwide register-based cohort study in Finland from 1998 to...
2018. We included all births from the Medical Birth Register, which covers 99.9% of births in Finland and contains information on all live and stillbirths with a gestational age ≥22+0 weeks or a birthweight ≥500 g. Information on injuries and surgical operations were retrieved from the Finnish Care Register for Health Care, which includes all visits and operations in specialized health care in Finland. Due to nationwide publicly funded health care, the coverage and validity of the Care Register is extremely high. Pubic symphysis rupture was classified based on the ICD-10 code S33.4 (Traumatic rupture of pubic symphysis). Information on pubic symphysis operations was gathered based on pelvis-specific operation codes of the Nordic NOMESCO classification. Diagnosis within 60 days of delivery was classified as related to delivery. Incidence per 100,000 deliveries with 95% confidence intervals (CIs) was calculated for symphysis rupture and surgery using Poisson’s exact test. Ethical committee approval was not required due to the register-based study design and because patients were not contacted. This study received research permission from the Finnish Data authority FINDATA, permission number: THL/1756/14.02.00/2020.

Results

We included a total of 1,175,326 deliveries from the Medical Birth Register. Of these, 991,053 (84%) were vaginal (spontaneous or assisted) and 201,414 (16%) were cesarean sections. During our study period, nine pubic symphysis injuries occurred during the intrapartum and puerperal periods and four were operated. For all operated women, surgery was performed during the first hospitalization period. The incidence of rupture was 0.8 per 100,000 deliveries (CI, 0.4–1.5) and incidence of operation was 0.3 per 100,000 deliveries (CI, 0.1–0.9). Corresponding incidences for vaginal deliveries were 0.9 ruptures per 100,000 deliveries (CI, 0.4–1.7) and 0.4 operations per 100,000 deliveries (CI, 0.1–1.0).

All symphysis pubis ruptures diagnosed during the intrapartum and puerperal periods occurred after vaginal delivery (Table 1). Mean birthweight was 3605 g and no perinatal mortality was observed. Outside of the intrapartum and puerperal periods, a total of 19 cases of symphysis pubis rupture were hospitalized during the 21-year study period, with a mean yearly cohort size of 1,181,104 women. Of these, eight women had undergone previous vaginal delivery, and seven nulliparous women had other major concurring fractures at the time of rupture.

Discussion

Our results suggest that birth-related ruptures of the pubic symphysis are rare events with an incidence of 0.8 ruptures per 100,000 deliveries and are mostly associated with vaginal delivery. In concordance with previous reports, ruptures are mostly treated conservatively. These figures are the first nationwide incidence figures published and remain lower than previously defined figures. Due to the predominant diagnostic criteria being a sufficiently widened radiological intrapubic diameter, diagnosis of pubic symphysis rupture does not distinguish between partial and total ligamentous rupture. From our data, we are unable to distinguish the exact cause of rupture, but for all women, the rupture of the symphysis pubis was the only traumatic diagnosis within 60 days of delivery. As a possible limitation of our results, it is plausible our figures only include radiologically verified ruptures possibly limited to highly symptomatic cases. We hope these results serve as a future epidemiological cornerstone for birth-related ruptures of the pubic symphysis.

Declaration of conflicting interests

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References
Incidence of lumbar discectomy during pregnancy and within 12 months post-partum in Finland between 1999 and 2017: a retrospective register-based cohort study

Nyrhi Lauri, Kuitunen Ilari, Ponkilainen Ville, Mäntymäki Heikki, Huttunen Tuomas, Mattila Ville

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Both lumbar disc herniation in the general population and lower back pain in the pregnant population are known to be common conditions. The physiological and anatomical changes during pregnancy may increase the risk of lumbar disc herniation. In this study, we aimed to report the incidence of lumbar discectomy during pregnancy and the first 12 months after delivery.

METHODS: A retrospective statistical analysis was performed to identify patients undergoing lumbar discectomy. The study population included all women aged 15 to 49 years with a lumbar discectomy or scheduled discectomy during pregnancy ending in delivery from 1st January, 1999 to 31st December, 2017. The control population was defined as women aged 15 to 49 years who had undergone lumbar discectomy or scheduled discectomy within 12 months postpartum in Finland between 1999 and 2017.

OUTCOME MEASURES: The incidence rates and their 95% confidence intervals were calculated for lumbar discectomy during pregnancy and within 12 months postpartum. The effect of smoking on surgery risk was reported using odds ratios. The total incidence of lumbar discectomy during pregnancy was 11 operations per 100,000 person-years with an incidence rate ratio (IRR) of 1.7 (95% CI 1.1−2.7). Caesarean section was more common among pregnant women (3.2) when compared with the age-adjusted incidence in the general population (0.2). 90-day reoperation rates were higher than in the general population with an IRR of 1.8 (95% CI 1.3−2.3).

RESULTS: In total, 91 discectomies were performed during pregnancy and 508 within 12 months postpartum. Women with active smoking before pregnancy were at a higher risk for lumbar discectomy during pregnancy (OR 2.0, 95% CI 1.2−3.2). Smoking during pregnancy and smoking during the first trimester were associated with an increased risk of lumbar discectomy during pregnancy (OR 1.7, 95% CI 1.0−2.7) and (OR 1.9, 95% CI 1.1−3.2), respectively.

CONCLUSION: The incidence of lumbar discectomy during pregnancy was higher than in the general population. Smoking before pregnancy increased the risk of lumbar discectomy during pregnancy. This study highlights the importance of smoking prevention during pregnancy to reduce the risk of lumbar discectomy.
Clinical Study

Incidence of lumbar discectomy during pregnancy and within 12 months post-partum in Finland between 1999 and 2017: a retrospective register-based cohort study

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Abstract

BACKGROUND CONTEXT: Both lumbar disc herniation in the general population and lower back pain in the pregnant population are known to be common conditions. The physiological and anatomical of the mother predispose to increased strain of the lumbar disc, whereas pregnancy may promote caution in physicians contemplating surgical care.

PURPOSE: We aimed to report the incidence of lumbar discectomy during pregnancy and 12 months postpartum in Finland between 1999 and 2017.

STUDY DESIGN: Retrospective register-based cohort study.

PATIENT SAMPLE: Using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register, all women aged 15 to 49 years with a lumbar discectomy or pregnancy ending in delivery from 1st January, 1999 to 31st December, 2017 were included.

OUTCOME MEASURES: Incidence rates and their 95% confidence intervals were calculated for lumbar discectomy. Incidence rate ratios (IRR) were calculated between the study population and the control population. The effect of smoking on surgery risk was reported using odds ratios.

METHODS: A retrospective statistical analysis was performed to identify patients undergoing lumbar discectomy during pregnancy or the first 12 months after delivery. Incidence rates were compared with the age-adjusted values of the age-matched female general population. The effect of smoking on the risk of lumbar discectomy was analyzed using age-adjusted odds ratios.

RESULTS: In total, 91 discectomies were performed during pregnancy and 508 within 12 months postpartum. The total incidence of lumbar discectomy during pregnancy was 11 operations per 100,000 person-years with an IRR of 0.2 (95% CI 0.1–0.2) when compared with the age-adjusted female general population. Women with active smoking before pregnancy were at a higher risk for lumbar discectomy during pregnancy (OR 2.0, 95% CI 1.2–3.2). Caesarean section was more common after lumbar discectomy (22%). No perinatal mortality was observed. During the first-year postpartum the rate of lumbar discectomy increased to 47 per 100,000 person-years with an IRR of 0.7 (95% CI 0.6–0.8). 90-day reoperation rates were higher than in the general population with an IRR of 1.7 (95% CI 1.1–2.7).

REFERENCES:

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CONCLUSIONS: Lumbar discectomy during pregnancy is rare, but smoking increases the risk. Lumbar discectomy during pregnancy seems to be safe for the neonate. Postpartum incidences increased towards the end of the first year, but remained below the rates in the general population with a higher risk for short-term reoperation. © 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

Keywords: Disc herniation; Discectomy; Epidemiology; Pregnancy; Postpartum

Introduction

Spinal disc herniation is a common condition with the prevalence of lumbar disc syndrome previously reported to be 5% in men and 4% in women [1–3]. For most new lumbar disc syndrome patients, symptoms resolve with conservative treatment and both surgical and nonsurgical treatment usually lead to desirable outcomes [4,5]. However, for those patients with symptoms persisting for more than several months, operative treatment with lumbar discectomy has been shown to be an effective form of treatment [6,7]. Some situations, for example cauda equina syndrome caused by lumbar disc herniation, are considered indications for emergency lumbar discectomy [8].

Lower back pain is a frequent symptom during pregnancy that is reported in up to 50% of women, most typically between the 5th and 7th month of pregnancy [9–11]. During pregnancy, the mother’s pelvis tilts anteriorly, which contributes to increased lumbar lordosis and the axial load of the spine [12]. These changes, together with the effects of hormones such as relaxin and oestrogen loosen the connective tissues, could place an increased strain on the lumbar disc annulus and the posterior longitudinal ligament, increasing the risk for disc herniation [13–15]. The surgical treatment of lumbar disc herniation with discectomy is associated with known risks for complications and reoperations [16–18]. Patient selection for surgical treatment is difficult when the risks for increased disc herniation are weighed against reports that over 85% of pregnant women with lumbar disc syndrome report symptom relief within 6 weeks. Opting for surgical treatment is further complicated when the prone position for spine surgery (and left lateral tilt in the third trimester) as well as the effects of anesthesia on the foetus are considered [19–22].

The incidence of lumbar disc herniation during pregnancy has previously been reported to be 0.1 per 100,000 pregnancies in a single-centre study, which is lower than the reported figure for the general population of the same age [23]. However, reliable nationwide values of lumbar discectomy have not previously been published. In the present study, we hypothesize that the incidence of lumbar discectomy during pregnancy and the first 12 months postpartum remains lower than in the general population and analyzed all occurrences of lumbar discectomy surgery in Finland between 1999 and 2017 to provide nationwide incidences.

Methods

Data for this nationwide retrospective register-based cohort study were obtained from the Finnish Health and Social Data Permit Authority (FinData) [24]. We combined data from the Finnish Care Register for Health Care and the Medical Birth Register. The Finnish Care Register includes hospital inpatient data as well as data from day surgeries and specialized outpatient care. The coverage and accuracy of the register regarding diagnoses and discharges has been proven to be excellent, although information regarding patient comorbidities is lacking [25–27]. The Medical Birth Register contains information on all pregnancies ending in delivery after gestational week 21+6 or foetal weight over 500 grams. The validity and coverage of the register is excellent and has been estimated to cover 100% of newborns in Finland [28].

Our study period was from 1st January, 1999 to 31st December, 2017. Patients were selected from the Care Register using all surgery codes for discectomy of the cervical, thoracic and lumbar disc coded with the Finnish version of the Nordic Medico-Statistical Committee classification (ABC01, ABC04, ABC07, ABC10, ABC13, ABC16, ABC17, ABC20, ABC23, ABC26) [29]. All female patients aged 15 to 49 years at the time of injury, defined as reproductive-aged by the World Health Organization, were included in the study [30].

The registers were combined after the individuals were pseudonymized by FinData, who also retained the pseudonymisation key. None of the authors had access to the key. FinData provided a safe, remote-controlled environment in which all files could be analyzed. Using information on date of birth and pregnancy duration from the Medical Birth Register, we were able to isolate incidents that occurred during or after pregnancy. In this study, the primary outcome was spine discectomy surgery. The formation of the study cohort is described in Fig. 1.

This study was granted research permission from the Finnish Health and Social Data Permit Authority FinData, permission THL/1756/14.02.00/2020. Our study was formatted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies (Supplementary file 1) [31].
Statistical analysis

Yearly incidence rates were calculated for lumbar discectomy. Separate calculations were made for surgeries performed during pregnancy and for those performed during the 12 months following delivery. Incidences are reported as operations per 100,000 person-years both during and after pregnancy. Incidences of lumbar discectomy during pregnancy were calculated using yearly delivery rates and an estimated pregnancy length of 39 weeks. As a control population, surgery incidences were calculated for the age-matched general population of women using yearly age-specific population values in Finland. Incidence rates for the control population were age-adjusted by the age distribution of pregnant and postpartum women. Due to Finnish legislation regarding patient anonymity, counts under five are not further specified. The surgery rates of pregnant and postpartum women were compared with those of the control population using IRR and 95% confidence intervals (CI). Poisson regression was used to calculate incidence rates. IRRs for revision surgery were calculated for both groups. Continuous variables were presented as median with interquartile range or as mean with standard deviation (SD) based on the distribution of the variable. Multivariable logistic regression was used to assess the age-adjusted effect of smoking on lumbar discectomy. Results are reported as odds ratios (OR) with 95% CIs. If a patient underwent multiple operations with an identical operation code during the follow-up period, the first operation was considered the primary operation and the time between the operations was calculated. Surgery was considered as a revision operation when the time between the second and primary operation was less than 90 days. For surgery during pregnancy, relevant variables of delivery were calculated. A Kaplan-Meier survival analysis was performed to visualize the timing of surgery, relative pregnancy duration and the number of months after delivery. Statistical analyzes were performed using R version 4.0.3 [32].

Results

Total operations

In Finland, a total of 91 lumbar discectomy operations were performed during pregnancy and 508 within 12 months postpartum between the years 1999 and 2017. The mean (SD) age of the patients who underwent lumbar discectomy during pregnancy was 30.6 (5.1) years and 31.3 (4.8) years for those patients who underwent lumbar discectomy within 12 months postpartum. During the follow-up period, yearly incidence rates remained stable. Moreover, fewer than 5 discectomy operations for thoracic and cervical disc herniations were observed during the entire study period. For our control population the mean (SD) age was 37.2 (8.0) years.

Lumbar discectomy during pregnancy

The total 19-year incidence of lumbar discectomy during pregnancy was 11 operations per 100,000 person-years (CI 9–14). Yearly incidence rates varied greatly between 5 and
21 per 100,000 person-years (Fig. 2). For the control population, the total incidence rate was 69 operations per 100,000 person-years (CI 68–70), yielding an IRR of 0.2 (CI 0.1–0.2). For women who underwent discectomy during pregnancy, 90-day reoperation rates were lower (1.1%) than those in the control population (2.2%) with an IRR of 0.5 (95% CI 0.1–3.5).

Most lumbar disectomies were performed during the first two trimesters of pregnancy with a mean pregnancy duration of 15+3 weeks at the time of surgery (Fig. 3). Only 12% of operations were performed in the third trimester. For women who underwent discectomy during pregnancy, no foetal mortality was observed (Table). Caesarean section was more common after lumbar discectomy during pregnancy (22%) when compared with pregnant women without (17%). Mean (SD) duration of pregnancy was 39+5 (+- 1) gestational weeks, with 36% of women being primiparous. Mean birthweight (SD) was 3,592 (+- 544) grams. In fewer than 5 cases, caesarean section was performed during the same hospitalisation period as the discectomy. Of those women who underwent lumbar discectomy during pregnancy, 27% were active smokers before pregnancy (n=24/89). For all pregnant women during our study period the respective figure was 17%. Furthermore, those women who were active smokers before pregnancy were at higher risk for lumbar discectomy during pregnancy (OR 2.0, CI 1.2–3.2).

**Lumbar discectomy within 12 months postpartum**

In our 19-year follow-up period, the total incidence of lumbar discectomy during the first 12 months after delivery was 47 operations per 100,000 person-years. Yearly incidence rates varied greatly between 29 and 81 per 100,000 person-years during our follow-up period (Fig. 4). The IRR

Table Characteristics of women undergoing lumbar discectomy during pregnancy and neonatal outcomes in these pregnancies/deliveries

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>During pregnancy (n = 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age, mean (SD)</td>
<td>31 (5)</td>
</tr>
<tr>
<td>Primipara, n (%)</td>
<td>33 (36%)</td>
</tr>
<tr>
<td>Gestational age, weeks (mean + SD)</td>
<td>39+5 ± 1</td>
</tr>
<tr>
<td>Vaginal delivery (n + %)</td>
<td>71 (78%)</td>
</tr>
<tr>
<td>Epidural analgesia (n + %)</td>
<td>39 (43%)</td>
</tr>
<tr>
<td>Weeks at time of surgery (mean)</td>
<td>15±3 ± 10</td>
</tr>
<tr>
<td>Perinatal mortality (n + %)*</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Birthweight (mean + SD)</td>
<td>3592g ± 544g</td>
</tr>
<tr>
<td>Apgar score (median + IQR)†</td>
<td>9 [9, 9]</td>
</tr>
<tr>
<td>Maternal smoking (n + %)</td>
<td>15 (16%)</td>
</tr>
</tbody>
</table>

*Stilbirths and deaths before age of 7 days.
† One-minute Apgar Score.
between lumbar discectomy within the first 12 months postpartum and the control population was 0.7 (CI 0.6–0.8).

When compared with the control population, the 90-day reoperation rate for women within 12 months postpartum was 3.7% with an IRR of 1.7 (CI 1.1–2.7). The incidence of discectomy slowly increased towards the end of the first year following delivery, with a mean operation occurrence at 6.8 months postpartum (Fig. 5). Of those women who underwent lumbar discectomy within the first 12 months following delivery, 18% were active smokers before becoming pregnant (n=86/481). The risk for lumbar discectomy in women who were active smokers before pregnancy was similar to that of non-smokers (OR 1.1, CI 0.9–1.4). However, there was a higher-odds for revision during the first 90 days following delivery with an OR of 2.0, but results were not statistically significant (CI 0.6–5.4).

Discussion

In our nationwide study, the incidence of lumbar discectomy, both during pregnancy and within 12 months postpartum, remained lower than in the control population of the same age. During pregnancy, the incidence for immediate reoperation was lower than in the control population with an IRR of 0.5, but higher during the first 12 months after pregnancy with an IRR of 1.7. In total, 88% of lumbar discectomies were performed during the first two trimesters. The rate of caesarean section was higher in women who underwent lumbar discectomy during pregnancy when compared with the whole study population. Only isolated cases of cervical and thoracic discectomies were performed during pregnancy and within 12 months postpartum.

There are no pre-existing reports regarding the incidence of lumbar discectomy during pregnancy or the period following delivery. We are therefore unable to compare our results to those of previous studies. However, whole-population values of lumbar discectomy have been previously reported to be between 170 and 220 per 100,000 person-years in the USA and approximately 20 per 100,000 person-years in Sweden [33,34]. In a recent study by Ponkilainen et al using data from the same registers as the present study, the total incidence of lumbar discectomy in male and female patients aged between 18 and 35 years in Finland was reported to have declined from 73 to 59 per 100,000 person-years between 1997 and 2018. This corresponds to our findings regarding young females in the general population [18]. Moreover, 90-day reoperation rates after lumbar discectomy for patients aged 18 to 39 years has previously been reported to be between 1.4% and 2% [16]. These rates are slightly below our reported figures of 2.2% for the general young female population but support our findings of a
higher 90-day reoperation rate of 3.7% postpartum. During pregnancy, 90-day reoperation rates were lower at 1.1%. The national rate of caesarean section has previously been reported to be 16.6% in Finland, which is slightly lower than the rate revealed for women undergoing lumbar discectomy during pregnancy in the present study [35]. Our reported rate of smoking (27%) for these women was higher than in the general female population of the same age (17%). Moreover, those women with a previous history of smoking were at higher risk for lumbar discectomy [36].

The lower incidence of lumbar discectomy during pregnancy reported in the present study is in line with our hypothesis and the findings of previous reports. Anatomical and hormonal changes during pregnancy predispose the mother to increased lumbar disc instability. There are, however, several concerns that require multidisciplinary planning when operating on a pregnant woman [37]. Technically, the implementation of lumbar discectomy during pregnancy differs in both patient positioning and the management of anesthesia [20,22]. In the first and early second trimesters, the prone position is possible. During the late second and third trimesters, however, lateral tilt positioning is recommended [20,38]. With well advanced pregnancies, caesarean section immediately before discectomy can also be considered [20]. These considerations, in conjunction with the low level of evidence, could very well lead to a reluctance to operate as the pregnancy progresses. This could also partly explain the lower reoperation rates in pregnant women. Although we are unable to specify patients’ specific indications for surgery, the lower incidences of lumbar discectomy during pregnancy and the first year postpartum are possibly attributable to prolonged conservative treatment in milder cases of disc herniation. Our results revealed a slight reduction in the rate of lumbar discectomy after the first trimester, with an even greater reduction when progressing to the third trimester, where surgery might be limited to emergency scenarios only. In our study, no foetal mortality was observed. Apgar scores and gestational age were also normal for newborns after lumbar discectomy during pregnancy.

Smoking has previously been shown to be a risk factor for lumbar disc herniation and our finding of a higher risk for lumbar discectomy for mothers with a history of smoking before pregnancy is in line with these findings [39]. Smoking has also previously been described as an independent risk factor for reoperation, which is also supported by our results [40].

After pregnancy, limitations on surgery due to the foetus are lifted, but the effects of anesthesia need to be considered during lactation. In Finland, it is recommended that mothers exclusively breastfeed for the first 4 months followed by complimentary breastfeeding up to 12 months after delivery [41]. The connective tissue metabolism modifying hormone relaxin also persists in the mother’s body after delivery [42]. This could at least partially explain the lower incidences of lumbar discectomy during the first months after delivery, and which seem to rise towards the end of the first year. The effects of relaxin and increased lumbar movement could also be a factor in the increased reoperation rates observed postpartum.

The main strength of our study is the excellent national coverage of operated lumbar discectomies, including all operations performed in both public and private hospitals [25,27]. Combined with the exceptional national coverage of the Medical Birth Register, we were able to collect nationwide data on lumbar discectomies in young reproductive-aged women with minimal selection bias. A secondary strength of our study is our long follow-up period of 19 years. The main limitation of our data is that only surgical operations are included, and we were unable to analyze those patients treated conservatively. As a secondary limitation, we are also unable to adjust for patients’ comorbidities in our analyzes.

Conclusion

Our results suggest that lumbar discectomy is rarely performed during pregnancy with an incidence of 11 operations per 100,000 person-years. Moreover, operative treatment is seemingly safe for neonates. Operations are primarily performed during the first two trimesters of pregnancy with smoking as a risk factor. Operation rates slowly normalize towards the end of the first year postpartum, but reoperation rates remain higher than those in the general reproductive-aged female population.

Ethical review statement

According to Finnish research legislation and the Finnish National Board on Research Integrity appointed by the Ministry of Education and Culture, a review by a formal ethics committee is not required for research involving public and published data, registry and documentary data, and archive data.

Declarations of competing interest

None were declared.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2022.10.015.

References

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References


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Nordic Centre for Classifications in Health Care. NOMESCO Classi-

cation of Surgical Procedures (NCSP), version 1.15 2010.

World Health Organisation. Reproductive Health Indicators - guide-

lines for their generation, interpretation and analysis for global moni-

toring. 2006.

von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenberg-

broucke JP, et al. The Strengthening the Reporting of Observational

Studies in Epidemiology (STROBE) statement: guidelines for report-

doi.org/10.7326/0003-4819-147-8-200710160-00010.


Keskimaani I, Setisalo S, Osterman H, Rissanen P. Reoperations after

lumbar disc surgery: a population-based study of regional and inter-

doi.org/10.1097/00007632-200006150-00008.


https://doi.org/10.1097/00007632-200006150-00008.

https://doi.org/10.1097/00007632-200006150-00008.


ACOG. Committee opinion no. 775 summary: nonobstetric surgery
doi.org/10.1097/AOG.0000000000002375.

Nordic Centre for Classifications in Health Care. NOMESCO Classi-

cation of Surgical Procedures (NCSP), version 1.15 2010.

World Health Organisation. Reproductive Health Indicators - guide-
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von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenberg-
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ACOG. Committee opinion no. 775 summary: nonobstetric surgery
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Nordic Centre for Classifications in Health Care. NOMESCO Classi-

cation of Surgical Procedures (NCSP), version 1.15 2010.

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lines for their generation, interpretation and analysis for global moni-
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von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenberg-
broucke JP, et al. The Strengthening the Reporting of Observational

Studies in Epidemiology (STROBE) statement: guidelines for report-
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Incidence of Peripheral Nerve Decompression Surgery During Pregnancy and the First Year After Delivery in Finland From 1999 to 2017: A Retrospective Register-Based Cohort Study

Nyrhi Lauri, Kuitunen Ilari, Ponkilainen Ville, Jokihaara Jarkko, Huttunen Tuomas, Mattila Ville

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Key words: Carpal tunnel release, epidemiology, postpartum, pregnancy.

Type of study/level of evidence: Prognostic II.

We aimed to report the incidence of peripheral nerve decompression surgery during pregnancy and the first postpartum year in Finland from 1999 to 2017.

Purpose

In Finland, about 20% of women have a pregnancy after 35 years of age. The incidence of CTR in the general female population is 0.3 per 100,000 person-years. During the first 4 months of pregnancy, the incidence of CTR is similar to that in the general population. From the second trimester, the incidence of CTR is lower than that in the general population.

Methodology

Using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register, all women of potentially childbearing age (15-49 years) who underwent peripheral nerve decompression surgery or had a pregnancy ending in delivery from January 1, 1999, to December 31, 2017, were included. Incidence rates and incidence rate ratios were calculated for operations occurring during pregnancy and the first postpartum year. Logistic regression was used to assess the risk of undergoing CTR during pregnancy or the first postpartum year.

Results

In total, 308 women underwent carpal tunnel release (CTR) during pregnancy, and an additional 675 women underwent CTR within 12 months after delivery. The incidence of CTR in the general population during the study period was 1.2 per 100,000 person-years. During pregnancy, the incidence of CTR was 0.5 per 100,000 person-years. The incidence of CTR in the first postpartum year increased steadily during the first year, reaching those observed in the general population after the first year. Women who were active smokers before becoming pregnant were more likely to undergo CTR during pregnancy (odds ratio, 2.4; 95% CI, 1.3-4.1) and during the first postpartum year (odds ratio, 1.6; 95% CI, 1.3-2.1) when compared with that in the general population. Women who smoked were more likely to undergo CTR during pregnancy (odds ratio, 3.0; 95% CI, 2.2-4.0).

Conclusions

Carpal tunnel release is performed more rarely during pregnancy than in the age-adjusted general population (incidence rate ratio, 1.0; 95% CI, 0.9-1.1). The highest rates of CTR were observed during the first trimester. The incidence of CTR in the first postpartum year increased steadily during the first year, and after the first year, it was similar to that in the general population.

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Incidence of Peripheral Nerve Decompression Surgery During Pregnancy and the First Year After Delivery in Finland From 1999 to 2017: A Retrospective Register-Based Cohort Study

Lauri Nyrhi, MD,* † Ilari Kuitunen, MD, PhD,‡ Ville Ponkilainen, MD, PhD,* Jarkko Jokihaaara, MD, PhD,† || Tuomas T. Huttunen, MD, PhD,†¶ Ville M. Mattila, MD, PhD†||

**Purpose** We aimed to report the incidence of peripheral nerve decompression surgery during pregnancy and 12 months after delivery in Finland from 1999 to 2017.

**Methods** Using nationwide data from the Finnish Care Register for Health Care and the Finnish Medical Birth Register, all women of potentially childbearing age (15–49 years) who underwent peripheral nerve decompression surgery or had a pregnancy ending in delivery from January 1, 1999, to December 31, 2017, were included. Incidence rates and incidence rate ratios for operations were calculated for both childbearing women and the age-adjusted general female population.

**Results** In total, 308 women underwent carpal tunnel release (CTR) during pregnancy, and an additional 675 women underwent CTR within 12 months after delivery. The incidence of CTR during pregnancy was 38 per 100,000 person-years, with an incidence rate ratio of 0.5 (95% CI, 0.4–0.6), when compared with that in the general population. Women who were active smokers before becoming pregnant were more likely to undergo CTR during pregnancy (odds ratio, 2.4; 95% CI, 1.8–3.0). The highest rates of CTR were observed during the first trimester. The incidence of CTR in the first postpartum year increased steadily during the first 4 months to 79 per 100,000 person-years. During the latter 8 months, incidences were similar to those in the general population (incidence rate ratio, 1.0; 95% CI, 0.9–1.2). Women who smoked were more likely to undergo CTR during the first postpartum year (odds ratio, 1.6; 95% CI, 1.3–1.9).

**Conclusions** Carpal tunnel release is performed more rarely during pregnancy than in the age-matched general population. Postpartum incidences increased toward the end of the first year, reaching those observed in the general population after the first 4 months. Smoking before pregnancy is associated with increased incidences of CTR both during pregnancy and the first year after delivery. (J Hand Surg Am. 2023;48(5):452–459. Copyright © 2023 by the American Society for Surgery of the Hand. All rights reserved.)

**Type of study/level of evidence** Prognostic II.

**Key words** Carpal tunnel release, epidemiology, postpartum, pregnancy.
PERIPHERAL NEUROPATHIES ARE common conditions that affect a large number of pregnant women, with new symptoms or preexisting conditions that worsen during pregnancy.1,2 Although diabetes and thyroid disease are known predisposing factors, most conditions are attributed to the anatomical and hormonal changes associated with pregnancy, and often, no clear etiology can be demonstrated.1 The most common peripheral neuropathies during pregnancy and the subsequent lactation period are facial palsy, carpal tunnel syndrome (CTS), and meralgia paresthetica of the thigh.1,3–5 However, most pregnancy-related neuropathies usually resolve with nonsurgical treatment after pregnancy, and surgery is rarely required.1,2

By far, the most common neuropathy in pregnant women is CTS.6 The reported incidences of CTS during pregnancy vary greatly, from <1% to >60%.7–9 For most patients, symptoms seem to resolve by the end of the lactation period when the hormonal activity of the mother normalizes.5,10,11 Pregnancy-related CTS is usually managed nonsurgically, and surgical treatment with carpal tunnel release (CTR) is reserved for severely symptomatic patients or those with progressing symptoms after delivery.12,13

Previously, reports regarding the incidence of CTR during pregnancy have been restricted to case series and cohort studies for an otherwise widespread procedure.10,14,15 Moreover, there is a lack of reliable data in the literature regarding the incidence of CTR during pregnancy and the subsequent recovery period at the population level. On the basis of the findings of previous studies, we hypothesized that CTR is performed more rarely during pregnancy and the following postpartum period than in the general age-matched female population. Using nationwide registers in Finland from 1999 to 2017, we analyzed all occurrences of peripheral nerve decompression surgery to provide CTR incidences during pregnancy and the first year after delivery.

MATERIALS AND METHODS

Data for this nationwide retrospective register-based cohort study were obtained from the Finnish Health and Social Data Permit Authority (FinData).16 We combined data from the Finnish Care Register for Health Care and the Medical Birth Register. The Finnish Care Register includes hospital inpatient data and data from day surgeries and specialized outpatient care. The coverage and accuracy of the register regarding diagnoses and discharges have been proven to be excellent; however, information regarding patient comorbidities is lacking.17–19 The Medical Birth Register contains information on all pregnancies ending in delivery after gestational week 21 + 6 or with a fetal weight of >500 g. The validity and coverage of the register are excellent, and the register covers an estimated 100% of newborns in Finland.20

Our study period was from January 1, 1999, to December 31, 2017. Patients were selected from the Care Register using surgery codes for all surgical operations for peripheral neuropathies coded with the Finnish version of the Nordic Medico-Statistical Committee classification (Appendix 1, available online on the Journal’s website at www.jhandsurg.org).21 All female patients aged 15–49 years at the time of surgery, defined as fertile by the World Health Organization, were included in the study.22

The registers were combined after the individuals were deidentified by FinData, which also retained the deidentification key. FinData provided a safe, remote-controlled environment in which all data were analyzed. Using information on the date of birth and pregnancy duration from the Medical Birth Register, we were able to isolate the surgical operations that occurred during pregnancy and those that occurred within the first 12 months after delivery. In this study, the primary outcome was the incidence rate of surgery. Owing to the inability to distinguish between recurrent and contralateral conditions, only the first operation per patient was included in the study. The formation of the study cohort is described in Figure 1.

This study was granted research permission by FinData. According to Finnish research legislation and the Finnish National Board on Research Integrity appointed by the Ministry of Education and Culture, a review by a formal ethics committee is not required for research on public and published data, registry and documentary data, and archive data.23 Our study was formatted according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for observational studies (Table S1, available online on the Journal’s website at www.jhandsurg.org).24

Statistical analysis

Yearly incidence rates were calculated for surgery. Separate calculations were performed for surgery during pregnancy and the following 12 months after delivery. Incidences were reported as operations per 100,000 person-years both during and after pregnancy. Incidences during pregnancy were calculated using yearly delivery rates and an estimated pregnancy duration of 39 weeks. For the control
population, surgery incidences were calculated for an age-matched general population of women using yearly age-specific population totals in Finland. Incidence rates for the control population were age-standardized by calculating age-specific incidence rates weighted to match the age distribution of the postpartum women. According to Finnish legislature regarding patient anonymity, counts under 5 were not specified further. The surgery incidences of pregnant and postpartum women were compared with those of the control population using incidence rate ratios (IRRs) and 95% CIs, which were used to calculate incidence rates using Poisson regression. Continuous variables were presented as mean with SD based on the distribution of the variable. Data on maternal smoking were obtained from the Medical Birth Register, and multivariable logistic regression was used to assess the age-adjusted effect of smoking on CTR. Results were reported as odds ratios (ORs) with 95% CIs. A Kaplan-Meier survival analysis was performed to visualize the timing of surgery relative to pregnancy duration and the number of months after delivery.

RESULTS
Total operations
During the 19-year study period, a total of 308 women underwent CTR during pregnancy and 675 women underwent CTR during the first 12 months after delivery (1% and 3% of all operated women during the study period, respectively). The mean age (SD) of the patients who underwent CTR during pregnancy was 31.4 (5.2) years, whereas the mean age (SD) of the patients who underwent CTR during the first year after delivery was 33.0 (5.2) years. During follow-up, yearly incidence rates remained stable during pregnancy; however, an increasing yearly trend was observed in CTR during the first 12 months after delivery. In the control population, a total 23,651 females underwent CTR (96% of all operated women). In this group, the mean age was 40.3 (7) years. During the entire study period, a total of 10 ulnar nerve release procedures were performed during pregnancy, and an additional 16 were performed during the first 12 months after delivery. For other peripheral neuropathies, <5 operations were performed.

Carpal tunnel release during pregnancy
From 1999 to 2017, the incidence of CTR during pregnancy was 38 per 100,000 (95% CI, 34–43) person-years. Annual incidence rates varied greatly, ranging from 23 to 56 per 100,000 person-years (Fig. 2). For the control population, the total incidence rate was 77 per 100,000 (95% CI, 70–84) person-years, yielding an IRR of 0.5 (95% CI, 0.4–0.6).

The incidence of CTR was highest during the first trimester of pregnancy, with a mean pregnancy duration of 15.6 weeks at the time of surgery (Fig. 3). Moreover, only 16% of operations were performed during the third trimester. Of the 308 women who underwent CTR during pregnancy, 76 (25%) were active smokers before becoming pregnant. During the study period, 17% of all pregnant women smoked.
before becoming pregnant. Women who were active smokers before pregnancy were at a higher risk of undergoing CTR during pregnancy (OR, 2.4; 95% CI, 1.8–3.0). Prior pregnancies did not show increased odds of undergoing CTR during pregnancy (OR, 1.04; 95% CI, 0.8–1.4).
Carpal tunnel release during the first 12 months after delivery

The total incidence of CTR during the first 12 months after delivery in our 19-year follow-up period was 63 per 100,000 person-years (95% CI, 58–68). During the follow-up period, yearly incidence rates varied greatly between 35 and 95 per 100,000 person-years (Fig. 4). The IRR between CTR in women during the first 12 months after delivery and that in the control population was 0.8 (95% CI, 0.7–1.0).

The incidence of CTR was low immediately after delivery but increased during the first 4 months after delivery and reached the same level of incidence as that of the general population during the following 8 months. Surgery was performed a mean of 7.2 months after delivery (Fig. 5). In the first year after delivery, the incidence of CTR during the first 4 months was 32 per 100,000 person-years (95% CI, 26–38), which increased to 79 per 100,000 person-years (95% CI, 72–85) in the following 8 months. The IRR of CTR between the last 8 months of the first postpartum year and that in the control population was 1.0 (95% CI, 0.9–1.2). Of the 675 women undergoing CTR during the first 12 months after delivery, 118 (17%) were active smokers before pregnancy. The risk of undergoing CTR in women who were active smokers before pregnancy was higher than that in nonsmokers (OR, 1.6; 95% CI, 1.3–1.9).

DISCUSSION

In this nationwide study, the incidence of CTR during pregnancy was lower than that in the control population of the same age, with an IRR of 0.5. The incidence of CTR during pregnancy was highest in the first trimester, diminishing with the advancement of the pregnancy. After delivery, the incidence of CTR increased steadily, eventually reaching that of the control population during the latter 8 months of the first postpartum year. Active smoking before pregnancy increased the risk of undergoing CTR both during and after pregnancy. Only a few operations for other peripheral neuropathies were performed during pregnancy and the first 12 months after delivery.

Because of the lack of published results on the incidence of CTR during pregnancy or the first postpartum year in the literature, we were unable to directly compare our results with those of previous reports. Nevertheless, Burton et al14 described pregnant women as being less likely to undergo CTR (hazard ratio, 0.24; 95% CI, 0.21–0.28). In a recent study by Hulkkonen et al,25 the incidence of CTS in pregnant women was reported to be 260 per 100,000 person-years. In their 2006 study, Latinovic et al26 found that the incidence of CTS in females aged <35 years was 81.5 per 100,000 person-years. However, for females aged between 35 and 44 years, the incidence was 289 per 100,000 person-years. Previously, Pourmemari et al27 reported the
incidence of CTR in the general female population to be 220 per 100,000 person-years. Hulkkonen et al. described smoking as a risk factor for maternal CTS, with a hazard ratio of 1.5—1.9 for women. These results are in line with our finding of a higher incidence of CTR during pregnancy and the first 12 months after delivery among women who were active smokers before becoming pregnant.

Our finding of a lower CTR incidence during pregnancy when compared with that of females of a similar age in the general population is in line with our hypothesis and the findings of previous studies. Carpal tunnel syndrome has been previously shown to be most prevalent between the ages of 40 to 60 years, which explains the lower incidence of CTR in our age-matched control population. Hormonal and physiological changes during pregnancy predispose pregnant women to CTS, and the most common proposed etiology for CTS is fluid buildup in tissues in the carpal tunnel. However, altered insulin resistance and other hormonal changes may also have a metabolic effect on pregnancy-related CTS. Several methods, such as night splints and injections of corticosteroids, are used in the nonsurgical treatment of pregnancy-related CTS. Carpal tunnel release is typically performed for sleep-preventing persistent pain, motor deficit, or sensory loss. In addition to the preference for nonsurgical treatment of CTS during pregnancy, spontaneous recovery is usually expected, which further explains the lower incidences of CTR when compared with those in the general population. This may also explain why incidences of CTR reach those of the general population after the first 4 months after delivery when symptoms of pregnancy-related CTS are typically subsiding. Our results also revealed a major reduction in the rate of CTR after the first trimester. Postoperative rehabilitation is performed after CTR using dressings for varying lengths of time, and patients are discouraged from lifting or straining the operated hand for several weeks after surgery, which limits some of the mother’s physical capabilities. These factors can influence the surgeon’s decision-making toward nonsurgical treatment both during pregnancy and during the immediate postpartum period. The yearly incidence of CTR varied greatly during our study period. A generally increasing trend in the yearly incidence rates was observed toward the end of the study period. The same change was observed in both pregnant or postpartum and general populations, which could most likely be attributed to the generally increasing incidence of CTR.

Smoking has previously been described as a risk factor for CTS. However, smoking has also been
associated with CTS through atherosclerotic changes with a possibly ischemic mechanism and shown to slow down recovery from peripheral nerve damage.\textsuperscript{14,15} Our results showed an elevated risk of CTR among women who were smokers before pregnancy. This risk was higher during pregnancy but remained elevated throughout the first year after delivery. These results are in line with previous findings and suggest that smoking is a risk factor for CTR during pregnancy and the following recovery period.

The main strength of our study is the excellent national coverage of CTR incidence. Combined with the essentially perfect national coverage of the Medical Birth Register, we were able to collect nationwide data on CTR among women of childbearing age with minimal selection bias. A secondary strength of our study is the long study period of 19 years. The main limitation of our data is that only surgical operations were included. This meant that we were unable to analyze patients with CTS symptoms who were treated nonsurgically. Hence, our results only describe the incidence of surgical treatment, and we are unable to reflect on the duration or severity of symptoms. In addition, we were only able to distinguish the first CTR per patient; hence, we were unable to analyze bilateral CTR procedures or revision surgery. Owing to the limitations of our data, we were not able to include maternal body mass index, profession, or pregnancies ending in miscarriage before the gestational age of 22 weeks. For the same reasons, we were also unable to assess the influence of patients’ possible comorbidities on our results.

Our results suggest that CTR is rare during pregnancy, with an incidence of 38 per 100,000 person-years. Operations are primarily performed during the first trimester of pregnancy. Operation rates increase during the first 4 months after delivery, and the incidence is similar to that in the general population during the latter 8 months of the first year after delivery. Smoking increases the risk of undergoing CTR both during pregnancy and during the first year after delivery.

REFERENCES
