ARTICLE
Epidemiology

Pregnancy-related risk factors for sex cord-stromal tumours and germ cell tumours in parous women: a registry-based study

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BACKGROUND: Non-epithelial ovarian cancers are divided into sex cord-stromal tumours (SCSTs) and germ cell tumours (GCTs). Whereas parity and other pregnancy-related factors are protective for epithelial ovarian cancer, their associations with SCSTs and GCTs remains unclear.

METHODS: Using data from the medical birth registries from Denmark, Finland, Norway and Sweden, we compared all parous women with a diagnosis of SCSTs (n = 420) or GCTs (n = 345) 1970–2013 with up to 10 parous controls (SCSTs n = 4041; GCTs n = 2942) matched on the cases' birth year and country. We used conditional logistic regression to estimate odds ratios (ORs) with 95% confidence intervals (CIs) of associations between pregnancy-related factors and SCSTs and GCTs.

RESULTS: The risk of SCSTs, but not GCTs, decreased with higher age at last birth [≥40 versus <25 years: OR 0.48 (95% CI 0.23–0.98)]. The risk of SCSTs (but not GCTs) also decreased with shorter time since last birth. Number of births, preterm birth, preeclampsia, and offspring size were not associated with risk of SCSTs or GCTs.

CONCLUSIONS: We found a decreased risk of SCSTs with higher age at last birth and shorter time since last birth. The risk of SCSTs (but not GCTs) may be influenced by the woman’s reproductive history.

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BACKGROUND: Non-epithelial ovarian cancers are rare tumours that are classified as either sex cord-stromal tumours (SCSTs) or germ cell tumours (GCTs), each with several subtypes. The biology and tumour development are poorly understood and rarely studied in SCSTs (GCTs), each with several subtypes. The biology and tumour development are poorly understood and rarely studied in SCSTs (GCTs), each with several subtypes. The biology and tumour development are poorly understood and rarely studied in SCSTs (GCTs), each with several subtypes. The biology and tumour development are poorly understood and rarely studied in SCSTs (GCTs), each with several subtypes.

Non-parity and other pregnancy-related factors are protective for epithelial ovarian cancer, but their associations with SCSTs and GCTs remain unclear. In the largest study published to date, Adami et al. reported an association between increasing number of births and decreased risk of SCSTs. This case-control study was based on linked data from the nationwide and population-based medical birth registries (MBRs) and cancer registries in a Nordic collaboration. The methods used have been described recently. The MBRs contain information from antenatal, obstetric, and neonatal medical records and in the offspring.

Hence, there is reason to further investigate the influence of other pregnancy-related factors that might reflect hormonal exposure during pregnancy and a woman’s life, such as pregnancy length, age at births and offspring size.

We have performed a population-based case-control study with pooled data from four Nordic countries to allow an investigation of a large number of non-epithelial ovarian cancer cases. Our aim was to evaluate the risk of SCSTs and GCTs (in the mothers) in relation to pregnancy and birth characteristics. To have a homogenous study group with data on the factors of interest for this study, only parous women were included. By analysing the patterns of possible associations, we hope to increase our insight in the development of these rare tumours.

METHODS

Outcomes and definition of cases/controls

This case-control study was based on linked data from the nationwide and population-based medical birth registries (MBRs) and cancer registries in a Nordic collaboration, and the methods used have been described recently. The MBRs contain information from antenatal, obstetric, and neonatal medical records and
Statistical analyses to evaluate the most complete data. We also evaluated continuous time since last birth in categories of age at last birth to better clarify the relationship between these factors. We evaluated time since last birth in categories of age at last birth, or by <10 years of age at last birth, or by <10 years since last birth.

Exposures
We examined the following exposures: age at first and last birth; time since first and last birth; number of births at the time of matching; preeclampsia and twin/triplet pregnancy (in any pregnancy). Information on pregnancy length (in completed weeks) and offspring’s birth length and weight were recorded based on the most recent pregnancy before the case’s diagnosis to evaluate the most complete data.

Statistical analyses
We estimated odds ratios (ORs) with 95% confidence intervals (CIs) for the association between number of births and risks of subsequent SCSTs and GCTs using conditional logistic regression models (conditioned on birth year of the case and country). Analyses of other pregnancy and neonatal characteristics were analysed in models conditioned on matching factors and additionally adjusted for number of births. Birth length/weight, adjusted for pregnancy length (as a continuous variable), were assessed as a measure of foetal growth. All factors were examined as categorical variables, and as ordinal variables to test for trend (for offspring weight, trend was tested per 500 g). In analyses of pregnancy length, and birth length/weight of offspring, women who were diagnosed with non-epithelial ovarian cancer within six months after giving birth were excluded (SCSTs: six cases, GCTs: 32 cases), to minimise the possibility that associations were influenced by preterm delivery due to cancer. We performed a sensitivity analysis in which we excluded women who had only given birth once, since their age at first and last birth is the same. We also evaluated continuous time since last birth in categories of age at last birth to better clarify the relationship between these factors. All results were tested for heterogeneity (p-het) of associations between countries in stratified analyses, using a likelihood ratio test. R version 3.3.2 was used for all analyses.

RESULTS
We identified 420 cases of SCSTs in parous women, with a median age of 47 years (range 21–71) at diagnosis and 345 cases of GCTs in parous women, with a median age of 37 years (range 18–79).

Maternal characteristics and data on the offspring from the most recent pregnancy, stratified by case/control status, are presented in Table 1.

Risk factors for sex cord-stromal tumours
Higher age at last birth was associated with decreased risk of SCSTs [i.e. last birth at age ≥40, versus before 25 years: OR 0.48 (95% CI 0.23–0.98); per year increasing age: OR 0.97 (95% CI 0.94–0.99)]. A similar trend was seen with higher age at first birth [first birth at age ≥30, versus before 25 years: OR 0.70 (95% CI 0.47–1.05); per year increasing age: OR 0.97 (95% CI 0.94–1.00)]. SCST risk decreased gradually with higher age at first or last birth (Table 2). A recent childbirth (shorter time since first and last birth) was associated with decreased risk (Table 2). Increasing number of births was not associated with risk of SCSTs, nor were any of the other investigated factors. All results are presented adjusted for number of births, but unadjusted results were very similar (supplementary Table 2).

Risk factors for germ cell tumours
Age at birth was not associated with GCTs [i.e. last birth at age 30–39 versus before 25 years: OR 1.01 (95% CI 0.68–1.49)], nor were time since birth, number of births [per birth: OR 0.99 (95% CI 0.90–1.10)], or any of the other investigated factors.

Sensitivity analyses
We performed a sensitivity analysis for SCSTs in which we excluded women who had only given birth once, but the results were not altered [i.e. last birth at age 30–39, versus before 25 years: OR 0.61 (95% CI 0.41–0.90)]. The proportion SCSTs and GCTs differed between the Nordic countries, with a higher percentage of SCSTs in Norway and Sweden and a higher percentage of GCTs in Denmark and Finland (Table 1). However, when we stratified our analyses and tested for heterogeneity of associations among countries, the ORs between the pregnancy-related factors and SCSTs and GCTs did not differ (supplementary Table 3), suggesting there were no major differences in coding between the countries. We evaluated time since last birth in categories of age at last birth and vice versa (supplementary Table 4). The pattern was consistent across both, with reductions in risk for the recent births (whether categorised by ≥40 age at last birth, or by <10 years since last birth).

DISCUSSION
In this large study of non-epithelial ovarian cancer, we found that both higher age at last birth and shorter time since last birth were associated with decreased risk of SCSTs, but not with risk of GCTs. There was no association between number of births or any of the other investigated maternal or offspring factors and risk of SCSTs or GCTs.

Sex cord-stromal tumours
The evidence of a relation between age at birth and risk of SCSTs have so far been limited by few, and often small studies (summarised in supplementary Table 5). In the largest study to date, our findings of associations between higher age at last birth and shorter time since last birth and subsequent decreased risk of SCSTs, are, however, consistent with two smaller studies. A small Mexican case-control study,27 (based on three cases that were over 28 years of age at their last birth), and a study of Swedish women born 1925–1960 who were diagnosed with ovarian cancer during 1958–1984 (hence partly overlapping with this study), showed higher age at first birth tended to be associated with a decreased risk of SCSTs.10 In contrast, an older American study30 published in 1992 with 45 SCSTs found an increased risk with higher age at first birth and SCSTs. In this study, nulliparous women were included, and the results were based on only seven SCST cases that were
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Table 1. Maternal and offspring characteristics of non-epithelial ovarian cancer patients and matched controls, Nordic countries, 1970–2013a.

| Variable                      | Sex cord-stromal tumours | Controls | Germ cell tumours | Controls |
|-------------------------------|--------------------------|----------|-------------------|----------|
|                               | n  | %  | n  | %  | n  | %  | n  | %  |
| Total                         | 420 | 100 | 4041 | 100 | 345 | 100 | 2942 | 100 |

Maternal

Year of birth n % n % n % n %

1925–1939 34 8.1 334 8.3 16 4.6 159 5.4
1940–1949 140 33.3 1384 34.2 46 13.3 421 14.3
1950–1959 146 34.8 1405 34.8 113 32.8 1001 34.0
1960–1969 75 17.9 702 17.4 91 26.4 752 25.6
1970–1992 25 6.0 216 5.3 79 22.9 609 20.7

Country

Denmark 51 12.1 502 12.4 96 27.8 779 26.5
denmark

Finland 13 3.1 113 2.8 34 9.9 270 9.2

Norway 96 22.9 975 24.1 83 24.1 808 27.5

Sweden 260 61.9 2451 60.7 132 38.3 1083 36.9

Age at diagnosis/matching (years)

<40 110 26.2 958 23.7 233 67.5 1817 61.8

40–49 143 34.0 1418 35.1 65 18.8 653 22.2

50–59 117 27.9 1169 28.9 32 9.3 330 11.2

≥60 50 11.9 496 15.2 15 4.3 142 4.8

Age at first birth (years)

<25 131 46.3 1173 43.6 148 54.2 1123 49.5

25–29 98 34.6 907 33.7 91 33.3 780 34.4

≥30 54 19.1 613 22.8 34 12.5 366 16.1

Missing 137 – 1348 – 72 – 673 –

Age at last birth (years)

<25 70 16.7 484 12.0 86 24.9 583 19.8

25–29 137 32.6 1235 30.6 126 36.5 1072 36.4

30–39 198 47.1 2127 52.6 123 35.7 1176 40.0

≥40 15 3.6 195 4.8 10 2.9 111 3.8

Time since first birth (years)

<10 66 23.3 567 21.1 155 56.8 1103 48.6

10–19 84 29.7 790 29.3 74 27.1 728 32.1

20–29 89 31.4 914 33.9 32 11.7 325 14.3

≥30 44 15.5 422 15.7 12 4.4 113 5.0

Missing 137 – 1348 – 72 – 673 –

Time since last birth (years)

<10 136 32.4 1187 29.4 234 67.8 1824 62.0

10–19 114 27.1 1269 31.4 72 20.9 705 24.0

20–29 127 30.2 1170 29.0 28 8.1 319 10.8

≥30 43 10.2 415 10.3 11 3.2 94 3.2

Number of births

1 80 19.0 690 17.1 92 26.7 744 25.3

2 186 44.3 1771 44.1 148 42.9 1217 41.4

3 96 22.9 1007 24.9 71 20.6 607 20.6

≥4 58 13.8 563 13.9 34 9.9 374 12.7

Preeclampsia in any pregnancy

No 386 91.9 3735 92.4 326 94.5 2778 94.4

Yes 34 8.1 306 7.6 19 5.5 164 5.6

Multiple birth in any pregnancyb

No 410 97.6 3978 98.4 337 97.7 2877 97.8

Table 1 continued

| Variable                      | Sex cord-stromal tumours | Controls | Germ cell tumours | Controls |
|-------------------------------|--------------------------|----------|-------------------|----------|
|                               | n  | %  | n  | %  | n  | %  | n  | %  |
| Total                         | 420 | 100 | 4041 | 100 | 345 | 100 | 2942 | 100 |

Pregnancy length (weeks)c,d

≤36 19 4.6 195 4.9 12 3.9 158 5.7

37–41 347 84.4 3381 85.7 268 86.2 2389 85.9

≥42 45 10.9 371 9.4 31 10.0 233 8.4

Missing 3 – 35 – 2 – 30 –

Offspring length (cm)c,d

<48 31 7.6 351 8.9 17 5.5 253 9.2

48–54 357 87.7 3426 86.7 272 88.0 2361 85.4

≥54 19 4.7 176 4.5 20 6.5 151 5.5

Missing 7 – 29 – 4 – 45 –

Offspring weight (g)c,d

<2500 14 3.4 160 4.0 10 3.2 125 4.5

2500–4500 384 3.2 3694 9.2 293 93.9 2575 91.9

≥4500 14 3.4 124 3.1 9 2.9 102 3.6

Missing 2 – 4 – 1 – 8 –

aPercentages are presented without including missing cases.
bSex cord-stromal tumours: twin births: 10 cases/62 controls (2.4%/1.5%); triplets or greater: 0 cases/1 control (0%/0.02%). Germ cell tumours: twin births: 8 cases/63 controls (2.3%/2.1%); triplets or greater: 0 cases/2 controls (0%/0.07%).

*Excludes cases diagnosed with ovarian cancer within six months after giving birth (sex cord-stromal tumours: six cases, germ cell tumours: 32 cases).

over 29 years of age at their first birth, and the effect of age at last birth was not evaluated, restricting the generalisability of the findings.

Our finding with a lack of association between number of births and SCSTs is consistent with three previous studies, although one of them found an association between nulliparity and SCSTs, which we did not analyse. In addition, two other studies found an association between increasing number of births and decreased risk of SCSTs: The study, by Adami et al.,10 was comprised of data from an earlier calendar period when diagnostic criteria might not have been as well defined as today resulting in misclassified epithelial ovarian cancer cases. The second study, by Sanches-Zomorano et al.,7 was based on only 10 cases. All studies except Adami et al. included nulliparous women in their analyses. In light of our findings, and review of other studies, the impact of number of births on risk of SCSTs seems limited.

To our knowledge, prior investigations on preeclampsia, multiple birth and pregnancy length, and birth characteristics (offspring length and weight) on risk of non-epithelial ovarian cancer have not been performed. Our study does not, however, support associations between these characteristics and subsequent risk of SCSTs in the mother.

In summary, data from our large study suggest that older age at last birth, and shorter time since last birth affect risk of SCSTs. Results from previous studies are somewhat conflicting (summarised in subsequent Table 5). A hormonal influence in this subgroup is suggested by data from a 2011 Finnish study showing a positive association between higher levels of testosterone, androstenedione and 17-OH-progesterone concentrations during
Table 2. Risk of non-epithelial ovarian cancer by subtype for pregnancy, perinatal and birth characteristicsa.

| Cases/controls | Sex cord-stromal tumours | Germ cell tumours |
|----------------|--------------------------|-------------------|
|                | 420/4041 (54.9%)         | 345/2942 (45.1%)  |
| Mean/median age at diagnosis (range) | 48/47 (21–71) | 39/37 (18–79) |
| OR 95% CI      | OR 95% CI                |                   |
| **Age at first birth (years)** |                   |                   |
| <25            | 1.00 Ref                 | 1.00 Ref          |
| 25–29          | 0.91 0.67–1.24           | 0.98 0.71–1.34    |
| ≥30            | 0.70 0.47–1.05           | 0.93 0.59–1.47    |
| Per year age   | 0.97 0.94–1.00           | 1.01 0.98–1.05    |
| **Time since first birth (years)** |                   |                   |
| <10            | 0.53 0.23–1.19           | 1.20 0.36–3.96    |
| 10–19          | 0.69 0.35–1.35           | 1.03 0.34–3.15    |
| 20–29          | 0.80 0.47–1.38           | 0.96 0.37–2.53    |
| ≥30            | 1.00 Ref                 | 1.00 Ref          |
| Per year       | 1.03 1.00–1.07           | 0.99 0.95–1.02    |
| **Number of births** |                   |                   |
| 1              | 1.00 Ref                 | 1.00 Ref          |
| 2              | 0.97 0.72–1.29           | 1.19 0.88–1.60    |
| 3              | 0.89 0.64–1.24           | 1.19 0.83–1.70    |
| ≥4             | 0.96 0.65–1.41           | 0.95 0.60–1.50    |
| Per birth      | 0.96 0.87–1.05           | 0.99 0.90–1.10    |
| **Preeclampsia in any pregnancy** |                   |                   |
| No             | 1.00 Ref                 | 1.00 Ref          |
| Yes            | 1.09 0.75–1.58           | 1.08 0.65–1.78    |
| **Multiple birth in any pregnancy** |                   |                   |
| No             | 1.00 Ref                 | 1.00 Ref          |
| Yes            | 1.49 0.75–2.98           | 1.16 0.55–2.47    |
| **Pregnancy length (weeks)b,c** |                   |                   |
| ≤36            | 0.91 0.53–1.49           | 0.72 0.39–1.33    |
| 37–41          | 1.00 Ref                 | 1.00 Ref          |
| ≥42            | 1.18 0.84–1.64           | 1.23 0.82–1.85    |
| Per week       | 1.03 0.97–1.09           | 1.07 1.00–1.14    |
| **Offspring length (cm)b,c,d** |                   |                   |
| <48            | 0.90 0.59–1.37           | 0.64 0.37–1.13    |
| 48–54          | 1.00 Ref                 | 1.00 Ref          |
| >54            | 1.02 0.62–1.68           | 1.11 0.67–1.83    |
| Per cm         | 1.04 0.99–1.09           | 1.02 0.96–1.07    |

aOdds ratio (OR) and 95% confidence intervals (CIs) from conditional logistic regression models, conditioned on birth year (of the case) and country, adjusted for number of births.

bData from last pregnancy.

Data from last pregnancy.

dAdjusted for pregnancy length (last pregnancy) as a continuous variable.

pregnancy and risk of SCSTs. However; effects of 17-OH-progesterone might differ from those of progesterone, and timing of hormonal exposure in pregnancy may be important. Another Finnish study measured hormone levels during the first trimester in women with singleton pregnancies, and found that maternal age was associated with sex steroids concentrations, with higher progesterone concentrations and lower androgen and oestradiol in women >30 years of age. An American study from 2008 found similar results with a positive association between higher maternal age and levels of progesterone, and inverse associations with androgen and oestrogen. This could be a possible explanation for the decrease in risk of SCSTs with higher age at last birth, with progesterone levels associated with a decrease in risk and androgens with an increase in risk. A risk decrease with increasing progesterone levels has been raised as a potential protective factor for epithelial ovarian cancer through cell clearance of pre-malignant cells (reviewed in ref. 27) and indicates similar mechanisms for SCSTs and epithelial ovarian cancer. The increased risk with increasing androgen and oestradiol concentrations is generally consistent with SCSTs being rare before puberty, when hormone levels are low. These hormones are likely needed for tumour development or progression.

Germ cell tumours

Our finding of a lack of association between age at birth and GCTs is consistent with two previous studies. A Norwegian cohort study, including 71 cases of GCTs diagnosed 1960–1991 (hence partly overlapping with our study), found an increased risk of GCTs with high-aged childbirths. This result was, however, based on only 40 parous women. As in previous studies, we saw no association between number of births and GCTs. Neither did we see any associations between the analysed pregnancy and birth characteristics and subsequent risk of GCTs in the mother.

To summarise, a woman’s reproductive history does not seem to influence her risk of GCTs. Gonadal dysgenesis is associated with risk of GCTs, but not SCSTs. This suggests that development of GCTs is more genetically controlled, given that gonadal dysgenesis is secondary to chromosomal anomalies or mutations in genes related to the urogenital ridge or sex differentiation. This genetic component may also explain why there are no specific reproductive risk factors for GCTs, as opposed...
Changes in hormone levels during puberty might play a role, while the greater alterations during pregnancy have a more limited ability to affect risk because affected individuals would need to be very young at childbirth.

Strength and limitations

This population-based study is based on the largest number of SCSTs and GCTs reported to date. Despite the comparably larger sample size, statistical power was still limited, and confidence intervals were often wide suggesting that even larger studies are needed to reach firmer conclusions about associations that are likely modest. The cases numbers also limited our ability to separate the effect of the correlated factors of higher age at last birth and shorter time since last birth.

Among the strengths of this study is the almost complete information on the studied perinatal factors, based on mandatory reporting to birth registries which avoids recall bias. The nation-wide cancer registries in the four Nordic countries enabled identification of cancer cases in a similar and standardised manner. However, the proportions SCSTs and GCTs differed between the Nordic countries, which could imply differences in coding, genetics, or other risk factors, although there was no evidence of heterogeneity in the ORs by country.

While there are few, if any, established risk factors for non-epithelial ovarian cancer, it is unclear if the current study was missing information on important confounding factors, such as obesity, breast-feeding and oral contraceptive use. Oral contraceptives are associated with decreased risk of epithelial, and possible non-epithelial, ovarian cancer, but since data are scarce, their impact on SCSTs and GCTs remains uncertain. We also lacked information on oophorectomy/salpingectomy or hysterectomy, and thus could not exclude controls that had undergone gynaecological surgery. However, since the prevalence of women having gone through a oophorectomy/hysterectomy in the Nordic countries is low (200 per 100,000 women), and probably even lower in this young cohort, it is unlikely to have had a major effect on our risk estimates. Because our aim was to study the impact of pregnancy-related factors on risk of SCSTs and GCTs, we only included parous women in our study and results are thus generalisable to parous women only. This resulted in a higher mean age of GCT cases than in the general population and our inability to investigate the influence of early pregnancy loss (prior to week 22).

CONCLUSIONS

In this population-based case-control study, including 420 cases of SCSTs and 345 cases of GCTs among parous women, higher age at last birth, and shorter time since last birth, were both associated with a decreased risk of SCSTs, similar to results for epithelial ovarian cancer. Thus, it is possible that hormonal mechanisms or other mechanisms related to this aspect of reproductive history influence the development of both SCSTs (but not GCTs) and epithelial ovarian cancer. Number of births was not associated with the risk of SCSTs or GCTs. We found no associations with any of the investigated pregnancy-related factors and GCTs, suggesting that reproductive factors may have limited impact on risk of these uncommon tumours.

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AUTHOR CONTRIBUTIONS

Conception and design: C.S., T.B., A.E.K., A.E.N., M.G., T.G., A.G.O., S.T., R.T., H.T.S., I.G. Statistical analysis: C.S. Interpretation of data: C.S., I.G. Drafting of the manuscript: C.S. and I.G. with input from all authors. All authors discussed the results, contributed to the final manuscript, approved the final draft and decided to submit it for publication.

ADDITIONAL INFORMATION

Ethics approval and consent to participate This study obtained approval from the ethics committees in Norway and Sweden, from the Data Protection Agency in Denmark, and from the Finnish Institute for Health and Welfare in Finland after consultation with the data protection authority. The study was performed in accordance with the Declaration of Helsinki.

Consent to publish None.

Data availability The data in the current manuscript are results of linkages of several nationwide registers as described in the method section. Procedures for accessing the data will be available from the corresponding author.

Competing interests I.G. have received Honoraria from Janssen for projects unrelated to the current study. All other authors declare they have no conflicts of interest.

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