INTRODUCTION

In Finland, approximately 1.7% of live-born neonates are diagnosed with a birth injury. Most of the injuries are transient, but severe injuries can cause permanent disability and have lifelong consequences. The incidence of severe birth injury, including cranial hemorrhage, central nervous system injury, skeletal or visceral injury, and brachial plexus palsy (BPP), is reported to be between 0.2% and 0.5% in live births, and is mainly associated with vaginal deliveries. Since the incidence of birth injuries is low and a remarkable number of cases in

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Abstract

Objective: To examine severe birth-related injuries in neonates among mothers with different types of diabetes.

Methods: Retrospective cohort study based on Finnish Medical Birth Register data from 2004 to 2017. The study included singleton neonates born vaginally with cephalic presentation (n = 623 649) after 35+0 weeks of gestation. The primary outcome variable was severe birth injury. Incidences, crude and adjusted odds ratios, and probabilities in regression analysis were calculated for different types of diabetes.

Results: There were 1952/623 649 (0.3%) severe birth injuries of which brachial plexus injury occurred most frequently. The injury incidence was highest in neonates of women with type 1 or type 2 diabetes, 42/1659 (2.5%) and 10/548 (1.8%), respectively. For gestational diabetes, the injury incidence was comparable to non-diabetic women: 422/77 810 (0.5%) and 1478/543 632 (0.3%), respectively. Shoulder dystocia, high birthweight, and vacuum-assisted delivery were associated with the highest probability for injury. Birthweight and obesity had a stronger impact on injury risk in women with pregestational diabetes compared to other pregnancies.

Conclusion: Neonates of women with pregestational diabetes have a higher risk for severe birth injury than other neonates. The injury risk in neonates delivered by women with gestational diabetes or non-diabetic women is generally low.
the general population are unpredictable, it is important to explore the risk factors and incidences associated with high-risk pregnancies. Maternal diabetes is a risk factor for adverse perinatal outcomes. It increases the risk for macrosomia and shoulder dystocia (ShD), which are both known risk factors for birth injury. Maternal obesity, especially associated with gestational diabetes mellitus (GDM) and type 2 diabetes (T2D), is another risk factor for birth-related injuries. In Finland, the incidence of type 1 diabetes (T1D) is among the highest in the world, and the global incidence after 35 weeks of gestation in women diagnosed with T1D, T2D, or GDM has increased among women with diabetes. This study addresses severe birth injuries in vaginal deliveries after 35 weeks of gestation in women diagnosed with T1D, T2D, or GDM and compares the results to non-diabetic pregnancies. The study aims to describe the type of injuries, calculate the incidence rates, and determine the risk factors for severe injuries in a nationwide birth cohort study.

## MATERIALS AND METHODS

This nationwide population-based cohort study was conducted using data from the Finnish Medical Birth Register (MBR) and the Care Register for Health Care (CRHC), which are maintained by the Finnish Institute for Health and Welfare. The MBR includes data on all deliveries in Finland. The MBR comprises information on the health of the mothers and neonates, interventions needed during pregnancy, delivery, and the first 7 days after birth. The data are completed by information obtained from the Central Population Register and the Cause-of-Death Register. The CRHC contains information on patient characteristics, diagnoses, and operations performed during the hospital stay. The coverage and accuracy of these registers have been shown to be excellent.

The study was based on register data from the years 2004 to 2017. Gestational age was limited to between 35 and 42 weeks of gestation. After excluding those neonates delivered by forceps (n = 273, 0.03%) or those with major congenital anomalies (n = 18 854, 2.4%), 623 649 singleton live born neonates born vaginally with cephalic presentation were included. The outcome variables were severe birth-related injuries coded with the Finnish implementation of the 10th Revision of International Statistical Classification of Diseases and Related Health Problems (ICD-10) codes. The ICD-10 codes for birth injuries and complications have been shown to be excellent. The study aimed to explore the risk factors and incidences associated with high-risk pregnancies.

### TABLE 1 The frequency and incidence of individual types of severe birth injury associated with different types of diabetes among singleton vaginal deliveries with cephalic presentation between 35 and 42 gestational weeks from 2004 to 2017 in Finland

| Type of birth injury | ICD-10 codes | T1D (n = 1659) | T2D (n = 548) | GDM (n = 77 810) | No diabetes (n = 543 632) | Total (n = 623 649) |
|----------------------|--------------|---------------|---------------|------------------|--------------------------|---------------------|
| Intracranial hemorrhage or laceration | P10–P10.9 | 1 (0.06) | 1 (0.18) | 17 (0.02) | 59 (0.01) | 78 (0.01) |
| Severe central nervous system injury | P11.0–P11.2, P11.4–P11.5 | – (0.00) | – (0.00) | 2 (0.003) | 5 (0.001) | 7 (0.001) |
| Subaponeurotic hemorrhage | P12.2 | 2 (0.12) | – (0.00) | 19 (0.02) | 119 (0.02) | 140 (0.02) |
| Skull fracture, long bone injury / fracture | P13.0, P13.2, P13.3 | 3 (0.18) | – (0.00) | 12 (0.02) | 42 (0.008) | 57 (0.009) |
| Brachial plexus injury | P14.0–P14.3 | 36 (2.17) | 9 (1.64) | 372 (0.48) | 1253 (0.23) | 1670 (0.27) |
| Injury to the liver or spleen | P15.0, P15.1 | – (0.00) | – (0.00) | – (0.00) | – (0.00) | – (0.00) |
| Severe birth injury b | – | 42 (2.53) | 10 (1.82) | 415 (0.53) | 1467 (0.27) | 1934 (0.31) |
| Total | | 42 (2.53) | 10 (1.82) | 422 (0.54) | 1478 (0.27) | 1952 (0.31) |

Note: Data presented as number (% of live births).

Abbreviations: GDM, gestational diabetes; T1D, Type 1 diabetes; T2D, Type 2 diabetes.

aNot including clavicle fractures.

bComposite outcome, one or more injuries described above.

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years 2004 and 2005. Birthweights above +2 standard deviation (SD) were defined as large for gestational age (LGA) standardized for parity, sex and gestational age in a Finnish population. The use of oxytocin was registered if it was used to induce and/or augment labor. Spontaneous vaginal deliveries (SVDs) included spontaneous and induced deliveries as opposed to VAD.

Management of diabetic pregnancies are based on national guidelines and is uniform throughout the country. Women with pregestational diabetes or GDM needing pharmacological treatment for glycemic control are regularly guided by physicians and midwives specialized to treat diabetic pregnant women. According to guidelines delivery is recommended between 38 and 40 weeks of gestation for women with pregestational diabetes or GDM with pharmacological treatment, and before 41+3 for dietary treated GDM. The decision of the mode of delivery is based on the obstetrical indications if the estimated fetal weight by antenatal ultrasound is between 4000 and 4250 g in pregestational diabetes and up to 4500 g in medication treated GDM. Furthermore, an elective cesarean section is recommended if the estimated fetal weight is >4500 g in pregnancies with T1D, T2D and medication treated GDM. Mediolateral episiotomy is performed only when deemed necessary.

Birth injuries are primarily diagnosed by pediatric clinical examination. Radiologic evaluation is performed when severe birth injury is suspected and a specialized physician such as a pediatric surgeon is consulted.

2.1 Statistical analysis

The incidences of composite severe birth injury as well as individual types of injuries were calculated. Baseline characteristics were described as proportions for categorical variables and as means and SDs or medians with inter-quartile ranges for continuous variables. The background characteristics in different diabetes categories were compared using chi squared-test and Fisher's exact test for categorical variables and Welch Two Sample t-test and Mann-Whitney U-test for continuous variables. The risk factor analysis was calculated using a composite severe birth injury as an outcome variable. The results are presented as odds ratios (ORs), risk differences (RDs), and ratio of odds ratios (OR-ratios; the ratio of odds ratios for a severe birth injury with a given risk factor in diabetic groups versus non-diabetic group), with 95% confidence intervals (CIs). A logistic regression analysis was performed for the variables associated with the highest risk for injury. P-value of <0.05 was considered significant. Statistical analysis was performed using R Statistical Software version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).

2.2 Ethical approval

Only pseudonymized data were used. This study was approved by the Ethics committee of Tampere University Hospital (reference number R17069). Institutional approval was also obtained from the Finnish Institute for Health and Welfare (reference number THL/1659/5.05.00/2017).

3 RESULTS

The study population consisted of 623 649 neonates with 1952 severe birth injuries in 1934 pregnancies. The total incidence of injuries was 1952/623 649 (0.3%) of live births in vaginal deliveries (Table 1). The injury incidence was highest in women with T1D and T2D: 42/1659 (2.5%) and 10/548 (1.8%) of live births, respectively. BPP was the most frequent injury (n = 1670), accounting for 85.6% of all severe injuries. Other severe birth injuries were infrequent.

In diabetic pregnancies, labors were induced, oxytocin was used more often, and neonates were born earlier compared to non-diabetic pregnancies. In pregnancies with T1D ShD, LGA, and VAD occurred most often, whereas the incidences of VAD and ShD were similar between women with GDM and non-diabetic women (Table 2).

The strongest risk factors for severe birth injury were ShD, LGA, and VAD in all study groups (Table 3). The highest risk for injury was associated with ShD in all women. (T1D: OR 24.89, 95% CI 12.53–49.46, T2D: OR 114.86, 95% CI 16.53–797.94, GDM: OR 82.79, 95% CI 65.25–105.03, non-diabetic: OR 106.62, 95% CI 92.91–122.35). One-third of all neonates who experienced ShD had a severe birth injury. Based on OR-ratio, ShD was a more powerful risk factor for non-diabetic women compared to women with T1D, and a similar tendency was observed in pregnancies with GDM. The incidence of injuries among LGA newborns ranged between 214/8203 (2.6%) and 28/421 (6.7%), being highest in women with T1D. In total, from 505/55 443 (0.9%) to 6/67 (9.0%) of VADs resulted in injury, with the highest incidences in the T1D and T2D groups. Considering RDs, LGA and VAD only moderately increased the risk for injury. Primiparity and smoking were moderate risk factors for injury in women with T1D. Labor induction, use of oxytocin, and epidural or spinal anesthesia were associated with an increased risk for injury in women with GDM and non-diabetic women. Based on the RD, the increased probability of injury associated with these factors was, however, quite low (0.07%–0.34%, 95% CI 0.04–0.10% and 0.23–0.44%).

The probability of injury after SVD in pregnancies with T1D or T2D began to increase with a birthweight of more than 3900 g and more steeply with a birthweight of more than 4300 g. The risk was further increased in VAD (Figure 1, Table 4). However, for neonates born by SVD to women with GDM or non-diabetic women, the probability of injury remained low up to a birthweight of 4500 g. The effect of high birthweight on injury probability was clearly seen among neonates born by VAD to women with GDM or to non-diabetic women with a birthweight of more than 4300 g. High birthweight per se was a more important risk factor for injury than LGA (GDM's regression curve not shown).

A high BMI was associated with a risk for birth injury, but BMI had a lower impact than birthweight. Obesity was associated with...
pregnancies. This impact was further increased by vacuum extraction, which is in line with the findings of previous studies. ShD was the strongest risk factor associated with injury in all neonates irrespective of the diabetes status of the par- tum, which is in line with the findings of previous studies. Furthermore, the incidence of ShD was similar to that previously reported. Regarding BPP, however, the rates of injured neonates after ShD were higher than those reported in previous studies. The high comorbidity in the present study may be due to diverse diagnostic criteria or the broad coverage of the data, as we included all severe birth-related injuries diagnosed during the first year after birth. Moreover, we cannot rule out the possibility of underdiagnosing the milder forms of ShD without birth injury. The overall incidence of severe birth injury and the incidences of subaponeurotic hemorrhage and intracranial hemorrhage were comparable to those reported in previous studies (0.2%, 0.01%, and 0.02% of vaginal births, respectively).2

The distribution of severe birth injury, other than BPP, by different types of maternal diabetes has not previously been reported. The incidence of BPP among the neonates of diabetic women was similar (T1D: 2.2% of vaginal live births, GDM: 0.6% of vaginal live births), and the total incidence of BPP was higher than previously described in the literature (0.11% to 0.16% of vaginal births). ShD was the strongest risk factor associated with injury in all neonates irrespective of the diabetes status of the par-turient, which is in line with the findings of previous studies. Furthermore, the incidence of ShD was similar to that previously reported. Regarding BPP, however, the rates of injured neonates after ShD were higher than those reported in previous studies. The high comorbidity in the present study may be due to diverse diagnostic criteria or the broad coverage of the data, as we included all severe birth-related injuries diagnosed during the first year after birth. Moreover, we cannot rule out the possibility of underdiagnosing the milder forms of ShD without birth injury. The overall incidence of severe birth injury and the incidences of subaponeurotic hemorrhage and intracranial hemorrhage were comparable to those reported in previous studies (0.2%, 0.01%, and 0.02% of vaginal births, respectively).2

Baseline characteristics differed considerably between the types of diabetes, as reported earlier by others. T1D pregnancies had the highest incidences of the main risk factors, namely LGA, ShD, and VAD, explaining the high injury rate. Women with T2D and GDM had a higher BMI, and neonates were more often LGA compared with the neonates of non-diabetic women. Obesity, along with GDM and maternal pregestational diabetes, have been suggested to be independent risk factors for BPP. In this study, high BMI increased the risk for injury in neonates born by VAD in women with pregestational diabetes, but it was a less important risk factor in women with GDM and in non-diabetic women.

### Discussion

In this population-based study, the incidence of severe birth injury was highest in pregnancies complicated by T1D and T2D. Severe birth injuries, other than BPP, were infrequent. Risk factors were similar in diabetic and non-diabetic women, but high birthweight and obesity had a stronger impact on severe birth injuries in women with pregestational diabetes compared to GDM and non-diabetic pregnancies. This impact was further increased by vacuum extraction. The risk for injury in neonates delivered by women with GDM or non-diabetic women was generally low when labors complicated by ShD and the VAD of high birthweight neonates were excluded.

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### Table 2

|                        | T1D      | T2D      | GDM      | No diabetes |
|------------------------|----------|----------|----------|-------------|
| Live births            | 1659     | 548      | 77 810   | 543 632     |
| Spontaneous vaginal delivery | 1386 (83.5) | 481 (87.8) | 69 496 (89.3) | 488 189 (89.8) |
| Vacuum-assisted delivery | 273 (16.5) | 67 (12.2) | 8314 (10.7) | 55 443 (10.2) |
| Age (years)            | 29.7 ± 5.47 | 32.6 ± 5.68 | 31.0 ± 5.40 | 29.3 ± 5.26 |
| BMI (kg/m²)            | 25.9 ± 5.87 | 31.8 ± 7.50 | 28.0 ± 6.00 | 23.6 ± 4.20 |
| Smoking                | 279 (16.8) | 130 (23.7) | 14 454 (18.6) | 92 028 (16.9) |
| Primiparity            | 635 (38.3) | 174 (31.8) | 27 141 (34.9) | 219 207 (40.3) |
| Previous cesarean section | 193 (11.6) | 66 (12.0) | 7147 (9.2) | 36 180 (6.7) |
| Induction of labor     | 1056 (63.7) | 339 (61.9) | 25 145 (32.3) | 97 826 (18.0) |
| Use of oxytocin        | 994 (59.9) | 322 (58.8) | 39 509 (50.8) | 239 940 (44.1) |
| Epidural and/or spinal anesthesia | 1123 (67.7) | 359 (65.5) | 49 229 (63.3) | 325 482 (59.9) |
| Paracervical and/or pudendal block | 409 (24.7) | 141 (25.7) | 19 982 (25.7) | 126 000 (23.2) |
| Shoulder dystocia      | 60 (3.6) | 5 (0.9) | 477 (0.6) | 1617 (0.3) |
| Episiotomy             | 499 (30.1) | 93 (17.0) | 17 783 (22.9) | 134 882 (24.8) |
| LGA                    | 421 (25.4) | 55 (10.0) | 2835 (3.6) | 8203 (1.5) |
| Birthweight (grams)    | 3709.8 ± 494.52 | 3599.4 ± 471.04 | 3634.6 ± 479.86 | 3552.4 ± 463.86 |
| Gestational age (weeks) | 38 1/1 (37 1/1-39 6/7) | 38 6/6 (38 1/1-39 6/7) | 39 6/6 (39 10/10-40 6/6) | 40 1/1 (39 12/12-41 6/7) |
| Infant sex (boys)      | 775 (46.7) | 289 (52.7) | 39 839 (51.2) | 274 259 (50.5) |

Note: Data presented n (% of vaginal live births), mean ± SD or median with inter-quartile range.

Abbreviations: BMI, body mass index; GDM, gestational diabetes; LGA, large for gestational age; T1D, Type 1 diabetes; T2D, type 2 diabetes.
### Table 3

| Risk Factor                             | T1D | T2D | GDM | No diabetes |
|-----------------------------------------|-----|-----|-----|-------------|
| Number of live births                   | 1659| 548 | 77810| 543632      |
| Injured neonates (n)                    | 42  | 10  | 415 | 1467        |
| Shoulder dystocia (n)                   | 60  | 5   | 477 | 1617        |
| Injured neonates of total no. ne. with risk factor<sup>a</sup> | 17 (28.3) | 3 (60.0) | 116 (24.3) | 302 (18.7) |
| Injured neonates with risk factor of all injured neonates<sup>a</sup> | 17 (40.5) | 3 (30.0) | 116 (28.0) | 302 (20.6) |
| OR (95% CI)<sup>b</sup>                 | 24.89 (12.53–49.46) | 114.86 (16.53–797.94) | 82.79 (65.25–105.03) | 106.62 (92.91–122.35) |
| P<sup>c</sup>                           | <0.001 | <0.001 | <0.001 | <0.001 |
| RD (95% CI)<sup>d</sup>                 | 26.77 (16.92–39.21) | 58.71 (21.76–86.96) | 23.93 (20.30–27.98) | 18.46 (16.64–20.43) |
| OR-ratio (95% CI)<sup>e</sup>           | 0.23 (0.12–0.47) | 1.08 (0.15–7.52) | 0.78 (0.59–1.02) |
| LGA (n)                                 | 421 | 55  | 2853 | 8203        |
| Injured neonates of total no. ne. with risk factor<sup>a</sup> | 28 (6.7) | 2 (3.6) | 110 (3.9) | 214 (2.6) |
| Injured neonates with risk factor of all injured neonates<sup>a</sup> | 28 (66.7) | 2 (20.0) | 110 (26.5) | 214 (14.6) |
| OR (95% CI)<sup>b</sup>                 | 6.23 (3.25–11.95) | 2.29 (0.47–11.05) | 9.88 (7.92–12.33) | 11.42 (9.86–13.22) |
| P<sup>c</sup>                           | <0.001 | 0.303 | <0.001 | <0.001 |
| RD (95% CI)<sup>d</sup>                 | 5.52 (3.37–8.35) | 2.01 (1.04–10.74) | 3.47 (2.82–4.25) | 2.37 (2.05–2.74) |
| OR-ratio (95% CI)<sup>e</sup>           | 0.55 (0.28–1.06) | 0.20 (0.04–0.97) | 0.87 (0.66–1.13) |
| Vacuum-assisted delivery (n)            | 279 | 67  | 8314 | 55443       |
| Injured neonates of total no. ne. with risk factor<sup>a</sup> | 15 (5.5) | 6 (9.0) | 155 (1.9) | 505 (0.9) |
| Injured neonates with risk factor of all injured neonates<sup>a</sup> | 15 (35.7) | 6 (60.0) | 155 (37.4) | 505 (34.4) |
| OR (95% CI)<sup>b</sup>                 | 2.93 (1.54–5.58) | 11.73 (3.22–42.74) | 5.06 (4.14–6.18) | 4.66 (4.18–5.19) |
| P<sup>c</sup>                           | 0.001 | <0.001 | <0.001 | <0.001 |
| RD (95% CI)<sup>d</sup>                 | 3.55 (1.24–6.97) | 8.12 (3.17–17.38) | 1.49 (1.22–1.81) | 0.71 (0.64–0.80) |
| OR-ratio (95% CI)<sup>e</sup>           | 0.63 (0.33–1.21) | 2.52 (0.69–9.22) | 1.09 (0.87–1.36) |
| Primiparity (n)                         | 635 | 174 | 2714 | 219207      |
| Injured neonates of total no. ne. with risk factor<sup>a</sup> | 23 (3.62) | 4 (2.3) | 156 (0.6) | 622 (0.3) |
| Injured neonates with risk factor of all injured neonates<sup>a</sup> | 23 (54.8) | 4 (40.0) | 156 (37.6) | 622 (42.4) |
| OR (95% CI)<sup>b</sup>                 | 1.99 (1.07–3.68) | 1.44 (0.40–5.18) | 1.13 (0.92–1.37) | 1.09 (0.98–1.21) |
| P<sup>c</sup>                           | 0.029 | 0.733 | 0.256 | 0.105 |
| RD (95% CI)<sup>d</sup>                 | 1.77 (0.19–3.64) | 0.69 (1.62 to 4.26) | 0.06 (0.04 to 0.18) | 0.02 (0.005 to 0.05) |
| OR-ratio (95% CI)<sup>e</sup>           | 1.82 (0.98–3.41) | 1.32 (0.37–4.77) | 1.03 (0.82–1.29) |
| Smoking (n)                             | 279 | 130 | 14454 | 92028       |
| Injured neonates of total no. ne. with risk factor<sup>a</sup> | 13 (4.7) | 2 (1.5) | 84 (0.6) | 228 (0.3) |
| Injured neonates with risk factor of all injured neonates<sup>a</sup> | 13 (31.0) | 2 (20.0) | 84 (20.2) | 228 (15.5) |

(Continues)
High birthweight was the most important risk factor for birth injury. Although ShD is unpredictable, it is often associated with high birthweight, and high birthweight is suggested to be an independent risk factor for birth injury among neonates with ShD. In line with a previous publication, the birthweight per se was a more important risk factor for injury than LGA. The
importance of birthweight as a risk factor for birth injury was most clearly seen in T1D and T2D pregnancies and further strengthened by VAD. On the other hand, the probability of injury was almost the same when comparing the pregnancies of women with GDM and non-diabetic women and remained rather low with higher birthweights among SVD. Nevertheless, the probability of injury also began to rise with birthweights above 4000 g in the neonates of women with GDM, if VAD was required. This increased risk for injury in neonates born by VAD, especially those with high birthweight, is in concordance with previous reports.4,22 Approximately one-third of the injured neonates were born by vacuum extraction. Thus, promoting SVD may be one way to reduce the rate of birth injuries. The predictability of the risk of injury based on birthweight was less consistent in the neonates of women with GDM or in non-diabetic women than it was in women with pregestational diabetes. Perhaps because of the low incidences of ShD and LGA, the injuries among the neonates of non-diabetic women occurred less often concomitant with ShD or LGA than injuries associated with maternal diabetes. A similar relationship was also reported by Johnson et al.23

**FIGURE 1**  The probability of severe birth injury in relation to birthweight, diabetes type, and mode of delivery

**TABLE 4**  The probability of neonatal severe birth injury by diabetes type in singleton vaginal delivery with cephalic presentation between 35+0 and 42+6 gestational weeks

| Probability of severe birth injury in vaginal delivery % (95% CI)  |
|---------------------------------------------------------------|
| Birthweight 3000 g                                            |
| SVD              | 0.18 (0.13–0.26) | 0.19 (0.10–0.37) | 0.05 (0.04–0.06) | 0.03 (0.03–0.03) |
| VAD              | 0.91 (0.65–1.27) | 0.95 (0.50–1.80) | 0.24 (0.21–0.29) | 0.15 (0.13–0.17) |
| Birthweight 3500 g                                            |
| SVD              | 0.58 (0.42–0.80) | 0.61 (0.32–1.15) | 0.16 (0.14–0.18) | 0.10 (0.09–0.10) |
| VAD              | 2.83 (2.05–3.89) | 2.95 (1.57–5.47) | 0.77 (0.68–0.89) | 0.48 (0.43–0.52) |
| Birthweight 4000 g                                            |
| SVD              | 1.83 (1.33–2.50) | 1.91 (1.01–3.56) | 0.50 (0.45–0.55) | 0.31 (0.29–0.32) |
| VAD              | 8.48 (6.29–11.34)| 8.83 (4.85–15.54)| 2.42 (2.22–2.71) | 1.50 (1.39–1.62) |
| Birthweight 4500 g                                            |
| SVD              | 5.59 (4.12–7.55) | 5.83 (3.15–10.52)| 1.56 (1.40–1.74) | 0.96 (0.90–1.04) |
| VAD              | 22.77 (17.56–28.97)| 23.55 (13.92–36.96)| 7.32 (6.53–8.20) | 4.62 (4.23–5.05) |
| Birthweight 5000 g                                            |
| SVD              | 15.86 (11.94–20.75)| 16.45 (9.35–27.32)| 4.81 (4.24–5.44) | 3.01 (2.71–3.34) |
| VAD              | 48.40 (40.20–56.69)| 49.49 (33.86–65.23)| 20.09 (17.86–22.51)| 13.36 (12.0–14.56)|

Abbreviations: GDM, gestational diabetes; SVD, spontaneous vaginal delivery; T1D, Type 1 diabetes; T2D, Type 2 diabetes; VAD, vacuum-assisted delivery.
There is no standardized screening system or criteria for GDM. Indeed, it has been recently questioned whether the comprehensive screening of GDM and the treatment of mild hyperglycemia are worthwhile, and is the current system only increasing the number of women with GDM without improvement in outcomes.\textsuperscript{16,24} Nevertheless, it has been shown that there is a linear association between hyperglycemia and adverse pregnancy outcomes, and an association between mild untreated hyperglycemia and higher birthweight. Moreover, the treatment of GDM at least decreases the risk for ShD and high birthweight.\textsuperscript{4,25} In this study, the incidence of birth injury was comparable in the neonates of women with GDM and in non-diabetic women, suggesting that without screening and treatment the incidence may well have been higher.

The strengths of the present study are the statutory Finnish MBR and CRHC data with national coverage ruling out selection bias and increasing generalizability. The precision and completeness of the data have been reported to be good.\textsuperscript{17,18} In Finland, maternal and child welfare clinics are free of charge, ensuring equal opportunity for care and attendance by the entire pregnant population. The limitation of the study is the retrospective nature of the data. Moreover, the diagnostic criteria for GDM changed during the study period. Even with a large sample size, the number of T2D pregnancies remained modest, limiting the statistical power of the results. BPP, as the most common injury, influenced the results, and therefore the risk factors represent primarily risk factors for BPP.

5 CONCLUSION

The neonates of women with pregestational diabetes have a higher risk for severe birth injury than other neonates. The risk is strongly associated with ShD, higher birthweight and further strengthened by VAD. The incidence of injury in pregnancies with GDM is comparable with pregnancies without diabetes. Moreover, the impact of high birthweight and obesity on the risk for injury in GDM and non-diabetic pregnancies is less important than in women with pregestational diabetes.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest.

AUTHOR CONTRIBUTIONS

MK, TH, KT, HL, and AS designed the study. TH, AS, and MG contributed to the acquisition of the data. MK, TH, and TK were responsible for data analysis. All authors contributed to the interpretation of the data. MK was a major contributor in the writing of the manuscript. All authors participated in drafting and revising the manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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