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Incidence of obese parturients and the outcomes of their pregnancies: A nationwide register study in Finland

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ABSTRACT

Objectives: We analyzed the incidence of obese and severely obese parturients and the impact of maternal obesity on mode of delivery, perinatal and neonatal mortality, and neonatal health.
Study design: We included all singleton births from the medical birth register of Finland from 2004 to 2018 (n = 792 437). Maternal body mass index (BMI) was categorized into three classes: non-obese (BMI < 30 kg/m^2), obese (BMI 30 – 39.9 kg/m^2), and morbidly obese (BMI 40 kg/m^2 or more). The yearly incidence of obese and severely obese parturients per 10 000 births was calculated. Logistic regression was used to calculate adjusted odds ratios (aOR) with 95% confidence intervals (CI).
Results: Between 2004 and 2018, the incidence of obese and morbidly obese parturients increased by 44% and 103%, respectively. Cesarean section rates were 23.6% and 30%, respectively (aOR 1.63 CI 1.61 – 1.66 and 2.33 CI: 2.23 – 2.44). Neonates born to morbidly obese parturients had an increased need for intensive care unit treatment (aOR 2.21 CI: 2.10 – 2.32), higher perinatal mortality (aOR 1.65 CI: 1.28 – 2.14), and higher neonatal mortality (aOR 1.68 CI: 1.04 – 2.72). The need for neonatal intensive care (aOR 1.50 CI: 1.47 – 1.53), perinatal mortality (aOR 1.25 CI: 1.13 – 1.39), and neonatal mortality (aOR 1.33 CI: 1.09 – 1.62) increased also among obese parturients.
Conclusions: We report a worrying increase in obese and morbidly obese parturients. Neonates born to these parturients were more likely delivered by cesarean sections and had higher rates of perinatal and neonatal mortality, and intensive care unit treatment. This highlights the importance of preventing obesity among fertile-aged females.

Introduction

Obesity continues to rapidly increase globally [1]. As the incidence of obese fertile-aged females rises, the rate of obese parturients is also increasing [2]. Gestational diabetes mellitus rates have risen and will continue to do so in the future [2,3]. Maternal obesity has been associated with weakened neonatal health. For example, increased rates of birth traumas, neonatal intensive care, hypoglycemia, and perinatal mortality have been observed in both vaginal deliveries and cesarean sections [4,5]. Obese women are more likely to deliver by cesarean section [5,6] and require more intensive labor induction [6,7]. Furthermore, obese women are less likely to breastfeed their neonates [8]. However, the optimal delivery method for obese and morbidly obese parturients is not well studied [9]. In order to have up-to-date information on the current situation regarding obesity in pregnancy in Finland, we aim to report the incidence of obese and morbidly obese parturients in Finland, as well as the perinatal outcomes in vaginal deliveries and cesarean sections.

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Materials

Cohort selection

This retrospective nationwide register-based study used the medical birth register of Finland. We included all singleton births from 2004 to 2018. The register covers nearly 100% of all neonates born after gestational week 22 or with a birthweight over 500 g. We excluded multiple births, forceps deliveries, outside hospital births, and pregnancies with missing maternal BMI information, missing information on gestational age, or missing mode of delivery (Fig. 1). In Finland, gestational diabetes mellitus (GDM) is defined as a pathologic two-hour 75-g oral glucose tolerance test, and pathological findings are recorded in the register.

Exposure

Prepregnancy obesity was the main exposure. We calculated body mass index (BMI) from the prepregnancy maternal weight and height. BMI was divided into three categories, which were based on the World Health Organization (WHO) obesity classification: non-obese (BMI under 30 kg/m^2), obese (BMI 30 – 39.9 kg/m^2 including WHO obesity classes I and II), and morbidly obese (BMI 40 kg/m^2 or over including WHO obesity class III).

Outcomes

Our primary outcomes were the incidence of obese or severely obese parturients, the mode of delivery (classified as spontaneous vaginal delivery, vaginal breech delivery, vacuum-assisted vaginal delivery, elective cesarean section [CS], urgent CS, and emergency CS), perinatal mortality (i.e., all stillborn neonates after gestational week 22 and all neonatal deaths during the first seven days), neonatal mortality (neonates born alive but who died during the first seven days), and the need for neonatal intensive care unit treatment. Our secondary outcomes were related to neonatal health (e.g., phototherapy, antibiotic treatment). Regarding birthweight and appropriateness for gestational age, small for gestational age (SGA) was classified as a birthweight of less than −2 SD from the mean, while large for gestational age (LGA) was classified as a birthweight of more than +2 SD from the mean. These values were calculated according to the new Finnish growth references [10]. Apgar points were dichotomized as less than 7 and 7 or more. Umbilical artery or venous pH were also dichotomized. We used a cut-off value of 7.00, as neonates with lower pH are considered for the use of therapeutic hypothermia in Finland.

Statistics

We calculated the yearly incidence of obese and severely obese parturients per 10 000 births with a 95% confidence interval (CI). We used chi squared test for dichotomous outcomes and student's *t*-test for continuous outcomes and p-value under 0.05 was considered as statistically significant. We used logistic regression to analyze unadjusted and adjusted odds ratios (OR) for the primary outcomes (mode of delivery, perinatal mortality, neonatal mortality, and neonatal intensive care unit treatment). Covariates were selected based on the directed acyclic graphs for each main outcome (Figs. S1A-S1C). We included in the model maternal age and smoking during pregnancy. Because GDM was a mediator variable in the causal model, we estimated the impact of GDM by conducting a stratified analysis where obese and morbidly obese parturients with GDM were compared to non-obese parturients with GDM. Furthermore, we assessed the outcomes stratified by delivery method to estimate if any delivery method seemed safer for neonates. We included the same adjusting variables in these models. We used SPSS version 29.0 for statistical analysis. The directed acyclic graphs were made by using the free online software Daggity (daggity.net). We have reported this study according to the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE; Supplement 1).

Ethics

An ethical committee statement was not required due to the register-based design. The Finnish data authority Findata granted research permission to this study (permission number: THL/1756/14.02.00/2020).

Results

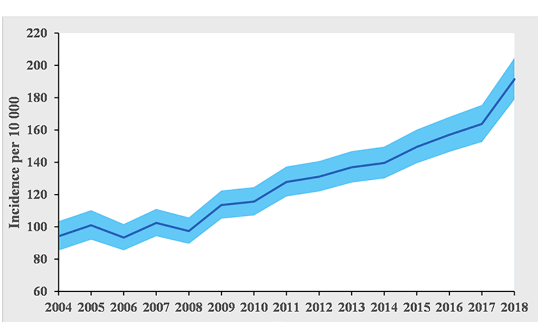
A total of 857 578 neonates were retrieved from the register and after excluding multiple births, forceps deliveries, and cases with missing information, 792 437 singleton-born neonates were included for analysis (Fig. S2).

Maternal obesity

According to maternal prepregnancy BMI, 87.5% of parturients were non-obese, 11.2% were obese, and 1.3% were morbidly obese. The incidence of obese parturients increased by 44% from 2004 (994per10000parturients) to 2018 (1432per10000) (Fig. 1A). The incidence of morbidly obese parturients increased by 103% from 2004 (94per10000) to 2018 (191per10000) (Fig. 1B).

Maternal background characteristics

Women in the non-obese group were more likely to be nulliparous, p < 0.001 (Table S1). Over 50% of parturients in the morbidly obese group had GDM. Higher rates of obese (19.1%) and morbidly obese parturients (21.0%) smoked during pregnancy compared to non-obese parturients



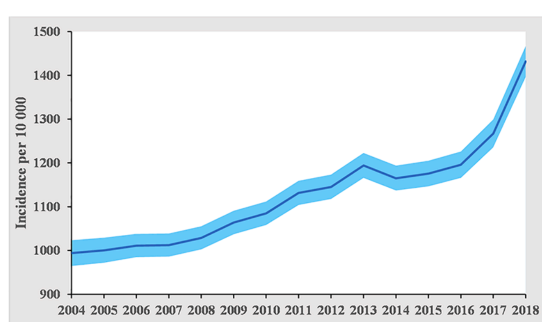


Fig. 1. A-B Yearly incidence of a) obese (maternal body mass index 30.0–39.9 kg/m^2) and b) severely obese (maternal body mass index 40.0 kg/m^2 or over) per 10 000 parturients in Finland from 2004 to 2018.

(14.1%), $p < 0.001$.

Delivery methods

Uncomplicated vaginal delivery was possible in most cases as 75.7% of non-obese, 69.8% of obese, and 63.6% of morbidly obese women had a spontaneous vaginal delivery, $p < 0.001$ (Table 1). A higher proportion of women had labor induction in morbidly obese and obese women than in non-obese, $p < 0.001$. Elective CS was more common among obese (8.9%) and morbidly obese (11.7%) parturients than among non-obese ones (5.9%). The rate of urgent CS was over two times higher among morbidly obese women (16.7%) compared to non-obese women (7.9%). Emergency CS rates were 1.3% among morbidly obese women and 1.1% among non-obese. The overall CS rate (including elective, urgent, and emergency CS) was highest among morbidly obese parturients (30.0%, aOR 2.33 CI: 2.23 – 2.44) and high among obese ones (23.6%, aOR 1.63 CI: 1.61 – 1.66) compared to non-obese parturients (14.8%) (Table 2). Stratified analyses by GDM showed that obesity seemed to be an independent risk factor for CS as obese women without GDM had higher odds for CS than non-obese women without GDM (Table 2).

Table 1
Mode of delivery and neonatal outcomes among non-obese (maternal body mass index less than 30.0 kg/m^2), obese (BMI 30.0 – 39.9 kg/m^2) and severely obese (BMI 40 kg/m^2 or more) parturients in Finland from 2004 to 2018.

	Non-obese		Obese		Morbidly obese		
	n	%	n	%	n	%	p-value
Mode of delivery							
Spontaneous vaginal delivery	525 574	75.7	62 146	69.8	6 398	63.6	<0.001
Breech delivery	4 567	0.7	370	0.4	34	0.3	<0.001
Vacuum-assisted delivery	61 412	8.9	6 371	7.2	646	6.4	<0.001
Elective CS	40 974	5.9	7 924	8.9	1 183	11.7	<0.001
Urgent CS	54 487	7.9	11 184	12.6	1 677	16.7	<0.001
Emergency CS	7 294	1.1	1 068	1.2	126	1.3	<0.001
Labor induction	131 764	19.0	28 311	31.8	4 270	42.4	<0.001
Shoulder dystocia	1 761	0.3	322	0.4	47	0.5	<0.001
Preterm, gestational age <37 weeks	29 980	4.3	4 713	5.3	601	6.0	<0.001
Birth weight (mean + sd, kilograms)	3.51	0.53	3.62	0.58	3.67	0.63	<0.001
Small for gestational age	22 775	3.3	2 401	2.7	301	3.0	<0.001
Large for gestational age	15 646	2.3	4 896	5.5	919	9.1	<0.001
Perinatal mortality	2 387	0.3	396	0.4	60	0.6	<0.001
Neonatal mortality	668	0.1	117	0.1	17	0.2	0.001
Resuscitation	5 192	0.7	818	0.9	134	1.3	<0.001
1 min Apgar points 0–6	37 372	5.4	6 443	7.2	944	9.4	<0.001
Umbilical arteria or vena pH <7.00	2 688	0.4	415	0.5	54	0.5	<0.001
Neonatal intensive care unit treatment	67 717	9.8	12 669	14.2	1 981	19.6	<0.001
Phototherapy	39 640	5.7	7 569	8.5	1 078	10.7	<0.001
Antibiotic treatment	35 920	5.2	6 453	7.2	994	9.9	<0.001

Neonatal outcomes

The perinatal mortality rate was highest in neonates born to severely obese parturients (0.6%) compared to obese (0.4%) and non-obese (0.3%) ones, $p < 0.001$ (Table 1). In the adjusted analysis, the aOR for perinatal mortality was 1.65 (CI: 1.28 – 2.14) among morbidly obese parturients and 1.25 (CI: 1.13 – 1.39) among obese compared to non-obese parturients (Table 2). Neonatal mortality was also higher among obese (aOR 1.33 CI: 1.09 – 1.62) and morbidly obese parturients (aOR 1.68 CI: 1.04 – 2.72). Perinatal mortality among obese parturients with GDM was similar (aOR 1.16 CI: 0.91 – 1.48) to that among non-obese parturients with GDM. The need for neonatal intensive care unit treatment was two times higher among severely obese parturients (19.6%) compared to non-obese (9.8%) aOR 2.21 (CI: 2.10 – 2.32) and it was seen both in parturients with and without GDM. Overall, the neonates born to morbidly obese women required more neonatal treatments (e.g., phototherapy, antibiotics, resuscitation), and were more often LGA compared to those born to non-obese women.

Delivery method and neonatal outcomes

Neonates born to morbidly obese parturients showed an increased need for intensive care unit treatment (aOR 2.09 CI: 1.95 – 2.24) and higher perinatal mortality (aOR 1.99 CI: 1.99 – 2.68) in spontaneous vaginal deliveries compared to non-obese parturients (Table 3). Neonatal mortality was higher among morbidly obese parturients in spontaneous vaginal deliveries, though this finding was highly uncertain (aOR 1.69 CI: 0.75 – 3.79). Among obese parturients, the need for intensive care (aOR 1.42 CI 1.39 – 1.47), perinatal mortality (aOR 1.32 CI: 1.16 – 1.50), and neonatal mortality (aOR 1.50 CI: 1.11 – 2.02) were higher in spontaneous vaginal deliveries. In vacuum-assisted deliveries neonates born to obese and severely obese parturients needed more intensive care unit treatment (Table 3).

Discussion

Main findings

We found an alarming increase in the incidence of obese and especially morbidly obese parturients. Morbidly obese parturients had twice as many elective and non-elective CS compared to non-obese parturients. Furthermore, perinatal, and neonatal mortality and the need for intensive care were more common among neonates born to obese and morbidly obese parturients. Stratified analysis by GDM showed that obesity was an independent factor for worse neonatal outcomes. Furthermore, stratified analysis by mode of delivery showed that obese women with spontaneous vaginal or vacuum-assisted delivery had the highest odds of neonatal mortality and that the risk of neonatal intensive care was higher with vaginal deliveries among both obese and morbidly obese than among non-obese women.

Interpretation

Our results on the increased incidence of obesity among parturients are in line with previous studies from Europe [11–14], North America [15,16], Africa [17], and Australia [18]. The increase of morbidly obese parturients is especially worrying as these women have been reported to have the highest rate of acute pregnancy complications, and complication risks in subsequent pregnancies are also increased [4–5,19–20]. Furthermore, infertility is more common in obese women [20]. Acute complications associated with obesity include preeclampsia, macrosomia, preterm birth, difficulties in labor induction, and prolonged labor [6,7,14,21,22]. These factors may explain the high rate of labor induction and at least some of the increased risk of CS among morbidly obese parturients (a two-fold increase in the rates of elective and urgent CS, though emergency CS rates were in line with the other groups). Previous

Table 2
Logistic regression analyses of main outcomes. Morbidly obese parturients and obese parturients compared to non-obese parturients. A stratified analysis was conducted where obese and morbidly obese parturients without GDM were compared to non-obese parturients without gestational diabetes mellitus (GDM) and similar was done for those with GDM. Unadjusted and adjusted odds ratios (OR) with 95% confidence intervals presented. Variables included in the adjusted model were maternal age and maternal smoking.

	Obese		Morbidly obese		Obese without GDM		Obese and GDM		Morbidly obese without GDM		Morbidly obese and GDM	
	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Cesarean section												
Unadjusted	1.68	1.66 – 1.71	2.43	2.32 – 2.53	1.62	1.59 – 1.66	1.44	1.39 – 1.49	2.41	2.24 – 2.56	1.89	1.78 – 2.01
Adjusted	1.63	1.61 – 1.66	2.33	2.23 – 2.44	1.60	1.56 – 1.63	1.44	1.39 – 1.49	2.35	2.21 – 2.51	1.92	1.80 – 2.04
Neonatal intensive care unit treatment												
Unadjusted	1.53	1.50 – 1.56	2.26	2.15 – 2.37	1.42	1.39 – 1.46	1.39	1.34 – 1.44	1.98	1.83 – 2.14	1.96	1.83 – 2.10
Adjusted	1.50	1.47 – 1.53	2.21	2.10 – 2.32	1.40	1.37 – 1.44	1.37	1.32 – 1.42	1.94	1.80 – 2.09	1.93	1.80 – 2.07
Perinatal mortality												
Unadjusted	1.29	1.16 – 1.43	1.72	1.33 – 2.22	1.45	1.28 – 1.63	1.13	0.89 – 1.45	2.01	1.44 – 2.82	1.71	1.13 – 2.56
Adjusted	1.25	1.13 – 1.39	1.65	1.28 – 2.14	1.42	1.25 – 1.60	1.16	0.91 – 1.48	1.96	1.40 – 2.74	1.75	1.15 – 2.66
Neonatal mortality												
Unadjusted	1.36	1.12 – 1.66	1.76	1.09 – 2.85	1.50	1.20 – 1.89	1.22	0.79 – 1.88	2.93	1.72 – 4.98	0.70	0.22 – 2.23
Adjusted	1.33	1.09 – 1.62	1.68	1.04 – 2.72	1.47	1.18 – 1.85	1.23	0.79 – 1.90	2.85	1.67 – 4.84	0.70	0.22 – 2.24

Table 3
Logistic regression analysis stratified by delivery method to analyze neonatal outcomes. Morbidly obese parturients and obese parturients compared to non-obese parturients. Unadjusted and adjusted odds ratios (OR) with 95% confidence intervals presented. Variables included in the adjusted model were maternal age and maternal smoking.

	Obese					Morbidly obese				
	Vaginal	Vacuum	Elective CS	Urgent CS	Emergency CS	Vaginal	Vacuum	Elective CS	Urgent CS	Emergency CS
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Neonatal intensive care unit treatment										
Unadjusted	1.46 (1.42–1.50)	1.58 (1.48–1.70)	1.43 (1.34–1.52)	1.24 (1.18–1.29)	1.24 (1.09–1.42)	2.14 (2.00–2.30)	2.18 (1.82–2.61)	1.93 (1.69–2.22)	1.60 (1.44–1.77)	1.45 (1.02–2.07)
Adjusted	1.42 (1.39–1.47)	1.56 (1.46–1.67)	1.42 (1.33–1.51)	1.23 (1.17–1.28)	1.22 (1.07–1.40)	2.09 (1.95–2.24)	2.13 (1.78–2.56)	1.92 (1.68–2.21)	1.57 (1.42–1.74)	1.43 (1.00–2.04)
Perinatal mortality*										
Unadjusted	1.36 (1.20–1.54)	1.38 (0.66–2.90)	1.11 (0.63–1.94)	1.13 (0.85–1.51)	0.64 (0.36–1.14)	2.08 (1.54–2.81)	1.70 (0.24–12.3)	0.99 (0.24–4.00)	1.06 (0.52–2.14)	0.84 (0.21–3.44)
Adjusted	1.32 (1.16–1.50)	1.31 (0.62–2.75)	1.11 (0.64–1.95)	1.10 (0.82–1.46)	0.62 (0.35–1.11)	1.99 (1.47–2.68)	1.64 (0.23–11.9)	1.00 (0.25–4.09)	1.00 (0.50–2.05)	0.80 (0.19–3.26)
Neonatal mortality**										
Unadjusted	1.52 (1.13–2.05)	1.75 (0.77–4.32)	0.99 (0.52–1.90)	1.06 (0.75–1.50)	0.49 (0.21–1.11)	1.74 (0.77–3.90)	4.32 (0.58–32.1)	N/A	1.27 (0.60–2.71)	0.69 (0.10–4.97)
Adjusted	1.50 (1.11–2.02)	1.71 (0.60–4.99)	1.02 (0.53–1.94)	1.05 (0.74–1.48)	0.47 (0.21–1.09)	1.69 (0.75–3.79)	4.37 (0.59–32.6)	N/A	1.24 (0.58–2.64)	0.66 (0.09–4.77)

*Perinatal mortality includes stillborn and neonatal deaths before the age of seven days.
**Neonatal mortality includes neonatal deaths before the age of seven days. Stillborns were excluded from this analysis.

studies have reported of increased risk of labor induction and unplanned CS due to failed labor induction among obese women [6,23]. The high rate of CS may also be due to the higher rate of previous CS in obese and morbidly obese women. Our finding, regarding the rate of CS, is in line with previous studies from Europe [7,24–27].

As a procedure, CS takes longer in a morbidly obese parturient [28]. Obese parturients also exhibit higher rates of CS complications, especially if done intrapartum [23,29]. The higher occurrence of CS among morbidly obese women is likely to negatively affect their health in later life [20]. Therefore, obesity-related difficulties with CS may encourage obstetricians to recommend the elective procedure to morbidly obese women to avoid the challenge of urgent or emergency CS. Obesity is also an independent risk factor for worse overall maternal pregnancy outcomes [22,30].

Our study shows that the odds of perinatal mortality are higher among obese and morbidly obese parturients. We present similar rates of perinatal mortality to those previously reported in Nordic countries among obese parturients [31]. However, our stillbirth rate among morbidly obese parturients (0.4 per 100 births) is lower than the previously reported stillbirth rate of 0.6 per 100 births in the United States (US) [32]. According to previous research [33], there is a positive correlation between maternal BMI and neonatal intensive care. Our study confirms this finding as the neonates born to morbidly obese parturients required more invasive care. Maternal morbid obesity has been previously linked to lower umbilical pH levels and an increased need for neonatal resuscitation [34]. Interestingly, however, in our study umbilical pH levels are not lower in obese and morbidly obese parturients. Neonates born to morbidly obese parturients have higher rates of phototherapy and antibiotic treatments [24], which was seen similarly in our results. According to our results, neonates born to obese and especially morbidly obese parturients are more likely to be LGA, as also reported by others [22]. Furthermore, our study shows that neonatal outcomes are linked to maternal obesity and are independent of GDM, which is in line with a previous Finnish register study [35]. According to the literature [36], high maternal age, combined with maternal obesity, increases neonatal deaths and preterm deliveries. However, in our age-adjusted analysis, obesity remains an independent risk factor for perinatal and neonatal mortality.

Scholars have debated the optimal delivery mode for morbidly obese parturients, as obese women and neonates are at an increased risk of complications regardless of mode of delivery [9]. In two cohort studies from the US and Norway [26,37], obesity was not associated with adverse perinatal outcomes in nulliparous women. A nationwide study from Sweden reported that the risk of adverse neonatal outcomes was associated with higher maternal BMI regardless of mode of delivery [5]. Moreover, in a retrospective cohort study from the US, a neonatal composite outcome for morbidity was higher after CS compared to after vaginal delivery [7]. Our results show that the odds for perinatal and neonatal mortality and intensive care unit treatment were higher among obese and morbidly obese women with spontaneous vaginal delivery or vacuum-assisted delivery. Among obese and morbidly obese parturients, the need for neonatal intensive care unit treatment was higher with all modes of delivery; however, the rate of perinatal mortality was higher mainly with spontaneous vaginal deliveries. These results should be interpreted with caution because our estimates suffer from high uncertainty due to the low event rates of mortality and severe morbid obesity. In previous studies, a possible explanation for the higher perinatal mortality among obese women has been the higher rate of stillbirths associated with obesity [32,38]. Dead fetuses are most often delivered vaginally, increasing the mortality rate of spontaneous vaginal deliveries. To address this issue, we excluded stillbirths and analyzed neonatal mortality alone, which showed a similar increase in the odds of adverse outcomes, especially in spontaneous vaginal and vacuum-assisted deliveries.

However, the odds for perinatal mortality were increased/higher in vaginal deliveries but not in CS compared to non-obese. The similar risk of perinatal mortality in CS deliveries might be due to the earlier decision about the urgent CS among obese than non-obese women to avoid difficulties associated with emergency CS and obesity. A higher rate of shoulder dystocia in obese women than in non-obese women may partly explain the increased risk of neonatal mortality in vaginal deliveries. Congenital anomalies, which are more common and have a lower detection rate among obese women [39], were not excluded in our study as this information was not available. Therefore, antenatal factors may have affected the higher mortality rate. Still, more attention should be paid to uncomplicated vaginal deliveries among obese parturients in order to understand and detect the potential risk factors of poor perinatal outcomes.

Alongside the immediate effects of maternal obesity on neonatal outcomes, recent studies have reported an increased risk of obesity, heart disorders, metabolic disorders, neurodevelopmental disorders, and growth disorders in the offspring of obese women [8,40]. CS itself changes the neonatal microbiome and worsens the risk of asthma, allergies, and obesity [11]. Therefore, unnecessary CS should be avoided, but the neonatal health can't be compromised.

Strengths and limitations

The main strength of our study is the use of a high-quality birth register, which enabled us to provide nationwide results. Furthermore, we used the directed acyclic graphs to present the causal pathways and compared to previous reports we stratified the analyses based on the maternal GDM instead of including it as a confounder in the models. An important limitation is the lack of information on preexisting maternal medical conditions, diagnoses given during pregnancy, and delivery, which is not comprehensively recorded in the register. Morbidly obese parturients have higher rates of preexisting conditions, such as pregestational diabetes and hypertensive disorders, which may have caused bias in our results. However, we were able to include in the analysis the information on GDM and smoking. A further limitation is the lack of CS indications, induction indications, and neonatal respiratory support methods as these are not reported to the register, although these would provide valuable additional information.

Conclusion

As the incidence of obese and morbidly obese parturients continues to rise, it is important to understand the negative effects this has on neonatal outcomes. Obese and morbidly obese women are more likely to deliver by elective and non-elective CS; their neonates require more intensive care unit treatment and have higher rates of mortality. The rates of adverse perinatal outcomes are higher in vaginal deliveries. This highlights the need for further discussion and prospective research on the best pregnancy follow-up and delivery method.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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None.

Data availability statement

Due to recent Finnish legislation on the secondary use of routinely collected health care data containing sensitive information, our data cannot be shared. To gain access to the data, interested persons should submit a study protocol to the Finnish data authority Findata. Currently, however, data cannot be delivered outside of Finland.

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None to report.

Author contributions

IK had the original idea and conceptualized the study with MK. IK and VP conducted the statistical analyses. TH supervised the project. IK wrote the initial draft. All authors participated on critical commenting and have approved the final version to be submitted. All of the authors had access to data and we take full responsibility of the data integrity.

Ethical approval

An ethical committee approval was not required due to the register-based design. The Finnish data authority Findata granted research permission to access the national register data after critical evaluation of our study protocols (permission number: THL/1756/14.02.00/2020).

References

[1] Jaacks LM, Vandevijvere S, Pan A, McGowan CJ, Wallace C, Imamura F, et al. The obesity transition: stages of the global epidemic. Lancet Diabetes Endocrinol 2019; 7(3):231–40. https://doi.org/10.1016/S2213-8587(19)30026-9.

[2] Agarwal P, Morriseau TS, Kereliuk SM, Doucette CA, Wicklow BA, Dolinsky VW. Maternal obesity, diabetes during pregnancy and epigenetic mechanisms that influence the developmental origins of cardiometabolic disease in the offspring. Crit Rev Clin Lab Sci 2018;55(2):71–101. https://doi.org/10.1080/10408363.2017.1422109.

[3] Saravanan P; Diabetes in Pregnancy Working Group; Maternal Medicine Clinical Study Group; Royal College of Obstetricians and Gynaecologists, UK. Gestational diabetes: opportunities for improving maternal and child health. Lancet Diabetes Endocrinol. 2020 Sep;8(9):793-800. doi: 10.1016/S2213-8587(20)30161-3.

[4] Smid MC, Vladutiu CJ, Dotters-Katz SK, Manuck TA, Boggess KA, Stamilio DM. Maternal super obesity and neonatal morbidity after term cesarean delivery. Am J Perinatol 2016;33(12):1198–204. https://doi.org/10.1055/s-0036-1586122.

[5] Blomberg M. Maternal obesity, mode of delivery, and neonatal outcome. Obstet Gynecol 2013;122(1):50–5. https://doi.org/10.1097/AOG.0b013e318295657f.

[6] Ellis JA, Brown CM, Barger B, Carlson NS. Influence of maternal obesity on labor induction: a systematic review and meta-analysis. J Midwifery Womens Health 2019;64(1):55–67. https://doi.org/10.1111/jmwh.12935.

[7] Paidas Teefey C, Reforma L, Koelper NC, Sammel MD, Srinivas SK, Levine LD, et al. Risk factors associated with cesarean delivery after induction of labor in women with class III obesity. Obstet Gynecol 2020;135(3):542–9. https://doi.org/10.1097/AOG.0000000000003703.

[8] Williams CB, Mackenzie KC, Gahagan S. The effect of maternal obesity on the offspring. Clin Obstet Gynecol 2014;57(3):508–15. https://doi.org/10.1097/GRF.0000000000000043.

[9] D'Souza R, Horyn I, Jacob C-E, Zaffar N, Horn D, Maxwell C. Birth outcomes in women with body mass index of 40 kg/m2 or greater stratified by planned and actual mode of birth: a systematic review and meta-analysis. Acta Obstet Gynecol Scand 2021;100:200–9. https://doi.org/10.1111/aogs.14011.

[10] Sankilampi U, Hannila ML, Saari A, Gissler M, Dunkel L. New population-based references for birth weight, length, and head circumference in singletons and twins from 23 to 43 gestation weeks. Ann Med 2013;45(5–6):446–54. https://doi.org/10.3109/07853890.2013.803739.

[11] Hartge D, Spiegler J, Schroeer A, Deckwart V, Weichert J. Maternal super-obesity. Arch Gynecol Obstet 2016;293(5):987–92. https://doi.org/10.1007/s00404-015-3921-9.

[12] Reynolds CME, Egan B, McMahon L, O'Malley EG, Sheehan SR, Turner MJ. Maternal obesity trends in a large Irish university hospital. Eur J Obstet Gynecol Reprod Biol 2019;238:95–9. https://doi.org/10.1016/j.ejogrb.2019.05.003.

[13] Chaparro MP, Ivarsson A, Koupil I, Nilsson K, Häggström J, de Luna X, et al. Regional inequalities in pre-pregnancy overweight and obesity in Sweden, 1992, 2000, and 2010. Scand J Public Health 2015;43(5):534–9. https://doi.org/10.1177/1403494815579478.

[14] Alexandra P, Vassilios B, Alexandra V, George K, Vassiliki L, Chryssa B. Population-based trends of pregnancy outcome in obese mothers: what has changed over 15 years. Obesity (Silver Spring) 2011;19(9):1861–5. https://doi.org/10.1038/oby.2010.317.

[15] Kim SY, Dietz PM, England L, Morrow B, Callaghan WM. Trends in pre-pregnancy obesity in nine states, 1993–2003. Obesity (Silver Spring) 2007;15(4):986–93. https://doi.org/10.1038/oby.2007.621.

[16] Driscoll AK, Gregory ECW. Increases in Prepregnancy Obesity: United States, 2016-2019. NCHS Data Brief. 2020 Nov;(392):1-8.

[17] Austin AM, Hill AG, Fawzi WW. Maternal obesity trends in Egypt 1995–2005. Matern Child Nutr 2013;9(2):167–79. https://doi.org/10.1111/j.1740-8709.2011.00346.x.

[18] Ward MC, Agarwal A, Bish M, James R, Faulks F, Pitson J, et al. Trends in obesity and impact on obstetric outcomes in a regional hospital in Victoria, Australia. Aust N Z J Obstet Gynaecol 2020;60(2):204–11. https://doi.org/10.1111/ajo.13035.

[19] Begum KS, Sachchithanantham K, De Somsubhra S. Maternal obesity and pregnancy outcome. Clin Exp Obstet Gynecol 2011;38(1):14–20.

[20] Chandrasekaran S, Neal-Perry G. Long-term consequences of obesity on female fertility and the health of the offspring. Curr Opin Obstet Gynecol 2017;29(3):180–7. https://doi.org/10.1097/GCO.0000000000000364.

[21] Kerbage Y, Senat MV, Drumez E, Subtil D, Vayssiere C, Deruelle P. Risk factors for failed induction of labor among pregnant women with Class III obesity. Acta Obstet Gynecol Scand 2020;99(5):637–43. https://doi.org/10.1111/aogs.13794.

[22] Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergström A, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: an individual participant data meta-analysis of European, North American and Australian cohorts. BJOG 2019. https://doi.org/10.1111/1471-0528.15661.

[23] Ashraf R, Maxwell C, D'Souza R. Induction of labour in pregnant individuals with obesity. Best Pract Res Clin Obstet Gynaecol 2022;79:70–80. https://doi.org/10.1016/j.bpobgyn.2021.12.004.

[24] Lynch CM, Sexton DJ, Hession M, Morrison JJ. Obesity and mode of delivery in primigravid and multigravid women. Am J Perinatol 2008;25(3):163–7. https://doi.org/10.1055/s-2008-1061496.

[25] Briese V, Voigt M, Hermanussen M, Wittwer-Backofen U. Morbid obesity: pregnancy risks, birth risks and status of the newborn. Homo 2010;61(1):64–72. https://doi.org/10.1016/j.jchb.2009.11.002.

[26] Pettersen-Dahl A, Murzakanova G, Sandvik L, Laine K. Maternal body mass index as a predictor for delivery method. Acta Obstet Gynecol Scand 2018;97(2):212–8. https://doi.org/10.1111/aogs.13265.

[27] Dalbye R, Gunnes N, Blix E, Zhang J, Eggebø T, Nistov Tokheim L, et al. Maternal body mass index and risk of obstetric, maternal and neonatal outcomes: a cohort study of nulliparous women with spontaneous onset of labor. Acta Obstet Gynecol Scand 2021;100(3):521–30.

[28] Girsen AI, Osmundson SS, Naqvi M, Garabedian MJ, Lyell DJ. Body mass index and operative times at cesarean delivery. Obstet Gynecol 2014;124(4):684–9. https://doi.org/10.1097/AOG.0000000000000462.

[29] Pallasmaa N, Ekblad U, Aitokallio-Tallberg A, Uotila J, Raudaskoski T, Ulander VM, et al. Cesarean delivery in Finland: maternal complications and obstetric risk factors. Acta Obstet Gynecol Scand 2010;89(7):896–902. https://doi.org/10.3109/00016349.2010.487893.

[30] Metsälä J, Stach-Lempinen B, Gissler M, Eriksson JG, Koivusalo S. Risk of pregnancy complications in relation to maternal prepregnancy body mass index: population-based study from Finland 2006–10. Paediatr Perinat Epidemiol 2016;30(1):28–37. https://doi.org/10.1111/ppe.12248.

[31] Kristensen J, Vestergaard M, Wisborg K, Kesmodel U, Secher NJ. Pre-pregnancy weight and the risk of stillbirth and neonatal death. BJOG 2005;112(4):403–8. https://doi.org/10.1111/j.1471-0528.2005.00437.x.

[32] Ikedionwu CA, Dongarwar D, Yusuf KK, Ibrahimi S, Salinas-Miranda AA, Salihu HM. Pre-pregnancy maternal obesity, macrosomia, and risk of stillbirth: A population-based study. Eur J Obstet Gynecol Reprod Biol 2020;252:1–6. https://doi.org/10.1016/j.ejogrb.2020.06.004.

[33] Sarkar RK, Cooley SM, Donnelly JC, Walsh T, Collins C, Geary MP. The incidence and impact of increased body mass index on maternal and fetal morbidity in the low-risk primigravid population. J Matern Fetal Neonatal Med 2007;20(12):879–83. https://doi.org/10.1080/14767050701713090.

[34] Ijäs H, Koivunen S, Raudaskoski T, Kajantie E, Gissler M, Vääräsmäki M. Independent and concomitant associations of gestational diabetes and maternal obesity to perinatal outcome: A register-based study. PLoS One. 2019 Aug 29;14(8):e0221549. doi: 10.1371/journal.pone.0221549.

[35] Lamminpää R, Vehviläinen-Julkunen K, Gissler M, Selander T, Heinonen S. Pregnancy outcomes of overweight and obese women aged 35 years or older – A registry-based study in Finland. Obes Res Clin Pract. 2016 Mar-Apr;10(2):133-42. doi: 10.1016/j.orcp.2015.05.008.

[36] Clark-Ganheart CA, Reddy UM, Kominiarek MA, Huang CC, Landy HJ, Grantz KL. Pregnancy outcomes among obese women and their offspring by attempted mode of delivery. Obstet Gynecol 2015;126(5):987–93. https://doi.org/10.1097/AOG.0000000000001084.

[37] Dashe, Jodi S, Donald D McIntire, and Diane M Twickler. "Effect of Maternal Obesity on the Ultrasound Detection of Anomalous Fetuses." Obstetrics and gynecology (New York. 1953) 113, no. 5 (2009): 1001–1007.

[38] Sanchez CE, Barry C, Sabhlok A, Russell K, Majors A, Kollins SH, et al. Maternal pre-pregnancy obesity and child neurodevelopmental outcomes: a meta-analysis. Obes Rev 2018;19(4):464–84. https://doi.org/10.1111/obr.12643.

[39] Persson M, Razaz N, Edstedt Bonamy AK, Villamor E, Cnattingius S. Maternal overweight and obesity and risk of congenital heart defects. J Am Coll Cardiol 2019;73(1):44–53. https://doi.org/10.1016/j.jacc.2018.10.050.

[40] Pirkola J, Pouta A, Bloigu A, Hartikainen AL, Laitinen J, Järvelin MR, et al. Risks of overweight and abdominal obesity at age 16 years associated with prenatal exposures to maternal prepregnancy overweight and gestational diabetes mellitus. Diabetes Care 2010;33(5):1115–21. https://doi.org/10.2337/dc09-1871.