Diabetologia (2012) 55:2327–2334
DOI 10.1007/s00125-012-2627-9

ARTICLE

Trends in maternal BMI, glycaemic control and perinatal outcome among type 1 diabetic pregnant women in 1989–2008

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Received: 12 March 2012 / Accepted: 24 May 2012 / Published online: 3 July 2012

Abstract
Aims/hypothesis Our objective was to examine the trends in prepregnancy BMI and glycaemic control among Finnish type 1 diabetic patients and their relation to delivery mode and perinatal outcome.
Methods We analysed the obstetric records of 881 type 1 diabetic women with a singleton childbirth during 1989–2008. Maternal prepregnancy weight and height were obtained from the maternity cards, where they are recorded as reported by the mother.
Results Maternal BMI increased significantly during 1989–2008 ($p<0.001$). The mean HbA_{1c} in the first trimester remained unchanged, but the midpregnancy and the last HbA_{1c} before delivery increased ($p=0.009$ and 0.005, respectively). Elective Caesarean sections (CS) decreased (p for trend <0.001), while emergency CS increased (p for trend <0.001). The mean umbilical artery (UA) pH decreased in vaginal deliveries (p for trend <0.001). The frequency of UA pH <7.15 and <7.05 increased (p for trend <0.001 and 0.008, respectively). The macrosomia rate remained at 32–40%. Neonatal intensive care unit (NICU) admissions increased (p for trend 0.03) and neonatal hypoglycaemia frequency decreased (p for trend 0.001). In multiple logistic regression analysis, maternal BMI was associated with macrosomia and NICU admission. The last HbA_{1c} value before delivery was associated with delivery before 37 weeks' gestation, UA pH <7.15, 1 min Apgar score <7, macrosomia, NICU admission and neonatal hypoglycaemia.
Conclusions/interpretation Self-reported pregestational BMI has increased and glycaemic control during the second half of pregnancy has deteriorated. Poor glycaemic control seems to be associated with the observed increases in adverse obstetric and perinatal outcomes.

Keywords BMI · Glycaemic control · Obesity · Perinatal outcome · Pregnancy · Type 1 diabetes

Abbreviations

CS	Caesarean section
EPO	Erythropoietin
HUCH	Helsinki University Central Hospital
NICU	Neonatal intensive care unit
UA	Umbilical artery

Introduction

The incidence of type 1 diabetes mellitus in Finland is among the highest in the world and is constantly increasing [1]. A similar trend is seen elsewhere in Europe and a doubling of new cases of type 1 diabetes in European children aged under 15 years has been forecast from 2005 to 2020 [2]. Consequently, a growing number of pregnant women have type 1 diabetes and are predisposed to perinatal complications associated with maternal hyperglycaemia, including congenital malformations, macrosomia and fetal asphyxia [3]. Numerous studies indicate

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that the rates of perinatal complications among type 1 diabetic patients are still substantially higher than those of the general population [4–11]. Only a few centres have shown improvement in the outcomes of type 1 diabetic pregnancies in recent decades [12, 13].

The rising incidence of type 1 diabetes and the global obesity epidemic have resulted in increasing obstetric challenges [14]. Good glycaemic control before and during pregnancy is the basis for improved pregnancy outcome among type 1 diabetic women [15, 16]. However, obesity and its associated increase in insulin resistance may impede the achievement of optimal glycaemia [17] and thus complicate the management of type 1 diabetic pregnancies. Perinatal complication rates are higher in women with gestational diabetes mellitus if they are obese [18]. Studies examining the trends in prepregnancy body weight and the consequences of overweight in type 1 diabetic pregnancies are lacking.

The objective of this study was to examine the temporal trends in prepregnancy BMI and glycaemic control during pregnancy among Finnish women with type 1 diabetes and their relation to delivery mode and perinatal outcome from 1989 to 2008.

Methods

Subjects We analysed the obstetric records of 881 consecutive type 1 diabetic patients with a singleton live birth between 1989 and 2008 at Helsinki University Central Hospital (HUCH). This hospital is the only centre treating pregnant type 1 diabetic patients in the greater Helsinki area and serves a population of about 1.5 million. Only the last pregnancy of each woman during this study period was included in the analyses.

Calculation of BMI Information on prepregnancy weight and height was obtained from the maternity care cards, where they are recorded as reported by the mother at the first maternity clinic visit, usually before 12 weeks' gestation. Women with a BMI ≥25.0–29.9 kg/m^2 were classified as overweight and those with a BMI ≥30.0 kg/m^2 were classified as obese. None had a BMI >40 kg/m^2.

Obstetric follow-up Patients with type 1 diabetes were referred to HUCH from primary healthcare centres and local hospitals as soon as pregnancy had been diagnosed, usually at 6–10 weeks' gestation. Approximately 40% of these women had attended the HUCH outpatient maternity clinic for prepregnancy care. The duration of pregnancy was confirmed by sonography at 11–13 weeks' gestation. During pregnancy, the patients visited the antenatal clinic every 2–4 weeks and more frequently during the last trimester. Fetal bioprofile and weight were estimated by ultrasound at each visit after 24 weeks' gestation.

Monitoring of glycaemic status The patients were advised to record their fasting blood glucose and all pre- and postprandial values on at least 2 days per week and take between three and five daily glucose measurements (fasting and pre- and/or postprandial values) on other days of the week. HbA_{1c} was assessed every 2–4 weeks by HPLC (Diamat; Bio-Rad Laboratories, Hercules, CA, USA). There was no change in the analysis method during the 20-year study period. During follow-up visits, glycaemic control was evaluated using home-monitored glucose and HbA_{1c} values. Insulin doses were adjusted as necessary. Three HbA_{1c} values were used for the purpose of this study: the first value measured in the first trimester; one measured in the second trimester between 18+0 and 22+0 gestational weeks; and the last value recorded before delivery. If two HbA_{1c} values had been measured between 18+0 and 22+0 gestational weeks, the average of the two values was used.

Obstetric and perinatal data collection The second highest systolic and diastolic blood pressure values in each trimester were recorded. Data on delivery mode, gestational age at birth, birthweight, umbilical artery (UA) pH at birth, 1 and 5 min Apgar scores, the lowest blood glucose value of the newborn infant, and neonatal intensive care unit (NICU) admission were obtained from patient records. UA samples were analysed for pH, acid base and haemoglobin concentration using Ciba Corning (Bayer Diagnostics, Fernwald, Germany/Siemens Healthcare Diagnostics, New York, USA), Rapidlab 800 (Bayer/Siemens) and ABL (Radiometer, Brønshøj, Denmark) pH/blood gas analysers.

Pre-eclampsia was defined as diastolic blood pressure ≥90 mmHg after 20 weeks' gestation, combined with new-onset proteinuria ≥0.3 g/24 h. Pregnancy-induced hypertension was defined similarly but without the presence of proteinuria. Patients with diabetic nephropathy (White class F) were excluded from the analysis of hypertensive complications. Diabetic nephropathy was defined as known nephropathy before pregnancy, or proteinuria >300 mg/24 h in the first trimester of pregnancy. Mild fetal asphyxia was defined as a UA pH <7.15 [19] and severe fetal asphyxia as a UA pH <7.05. Birthweights above 2 SD were defined as macrosomia and those below −2.0 SD as small-for-dates using a Finnish standard population standardised for sex and gestational age [20]. Neonatal hypoglycaemia was defined as a plasma glucose level <2.6 mmol/l during the first day of life. All neonatal glucose measurements were done in the hospital laboratory. Perinatal deaths in type 1 and type 2 diabetic pregnancies at HUCH in 1988–2008 have been recently published elsewhere [21].

Statistical methods Student's *t* test was used for continuous variables with a normal distribution. Linear regression analysis was used in the analysis of trends of continuous variables. Umbilical artery pH and gestational age were log-transformed before linear regression analysis because of a slightly skewed distribution. Categorical variables were tested with the χ^2 or Fisher's exact test and the Mantel–Haenszel linear-by-linear association χ^2 test. Multiple logistic regression analysis was used to assess the association of continuous and categorical variables with categorical outcomes. All tests used were two-sided and p values <0.05 were considered statistically significant. The statistical software used was IBM SPSS Statistics 20.0 (http://www-01.ibm.com/software/analytics/spss/products/statistics/).

Results

Maternal characteristics The maternal characteristics of the study population are presented in Table 1. Pregestational BMI shows an increasing trend (Table 1). In 1989–1992, the percentages of normal weight, overweight and obese type 1 diabetic pregnancies were 78.8%, 19.4% and 1.8%, respectively; whereas in 2004–2008 the corresponding percentages were 57.4%, 32.8% and 9.8%, respectively (p<0.001).

Glycaemic control The mean of the first HbA_{1c} in the first trimester remained unchanged during the study period, but the mean of the midpregnancy and the last HbA_{1c} concentrations before delivery increased (p for trend=0.009 and 0.005, respectively) (Table 2). The first HbA_{1c} value in the first trimester correlated positively with the last HbA_{1c} before delivery in linear regression analysis (r=0.52, p<0.001).

Hypertensive complications There were no significant changes in the frequencies of chronic hypertension, pregnancy-induced hypertension and pre-eclampsia during the study period (Table 1). In logistic regression analysis, pre-eclampsia was associated with delivery before 37 gestational weeks and with NICU admission of the infant (Table 3). Pregnancy-induced hypertension or chronic hypertension was not associated with NICU admission or preterm delivery.

Delivery mode The elective Caesarean section (CS) rate decreased and the emergency CS rate increased during 1989–2008, while the total CS rate decreased (Table 1). The rate of instrumental deliveries (vacuum extraction only) did not change (Table 1). In logistic regression analysis, the last HbA_{1c} value before delivery was associated with emergency CS (non-adjusted OR for each per cent increase in HbA_{1c} 1.43; 95% CI 1.23, 1.66). Maternal BMI was not associated with emergency CS (non-adjusted OR for each kg/m2 increase in BMI 1.02; 95% CI 0.98, 1.07).

Preterm birth Births before 32 weeks' gestation became less frequent during 1989–2008, but the trend for deliveries before 37 gestational weeks was not statistically significant (Table 4). The frequency of preterm deliveries did not differ between normal weight and obese pregnancies. In multiple logistic regression analysis, only the last HbA_{1c} before delivery and pre-eclampsia were positively associated with delivery before 37 weeks' gestation (Table 3).

Table 1 Maternal characteristics and obstetric outcomes of 881 type 1 diabetic women who delivered at HUCH in 1989–2008

Maternal characteristic/obstetric outcome	1989–1993 (n=172)	1994–1998 (n=190)	1999–2003 (n=190)	2004–2008 (n=329)	p for trend
Annual median number of singleton live births	32	41	38	70	
Age (years)	29.9 (5.1)	30.9 (4.7)	30.7 (5.2)	30.6 (4.9)	0.37
Nulliparous	68 (39.5)	65 (34.2)	85 (44.7)	143 (43.5)	0.12
Prepregnancy BMI (kg/m^2)	23.1 (2.7) [165]	24.1 (3.3) [181]	24.1 (3.1) [189]	24.8 (3.9) [326]	<0.001
Smokers	33 (19.3) [171]	23 (12.1)	37 (19.9) [186]	37 (11.6) [319]	0.09
Chronic hypertension	7 (4.8) [147]	4 (2.4) [164]	4 (2.3) [175]	18 (5.8) [313]	0.35
Pregnancy-induced hypertension	16 (10.9) [147]	22 (13.4) [164]	24 (13.7) [175]	38 (12.4) [313]	0.84
Pre-eclampsia	29 (19.4) [147]	34 (20.7) [164]	26 (14.9) [175]	53 (16.9) [313]	0.28
Total vaginal delivery rate	37 (21.5)	31 (16.3)	39 (20.5)	97 (29.5)	0.006
Vacuum extraction	3 (1.7)	1 (0.5)	5 (2.6)	11 (3.3)	0.09
Elective CS	103 (59.9)	112 (58.9)	88 (46.3)	123 (37.4)	<0.001
Emergency CS	32 (18.6)	47 (24.7)	63 (33.2)	109 (33.1)	<0.001
Total CS rate	135 (78.5)	159 (83.7)	151 (79.5)	232 (70.5)	0.006

The values are means (SD) or frequencies (%)

The number of patients is presented in square brackets if different

Table 2 Trends of the means (SD) of the first trimester, midpregnancy and last HbA_{1c} values before delivery among 881 type 1 diabetic women who delivered at HUCH in 1989–2008

Trimester	HbA_{1c}	*n*
1989–1993		
First trimester	7.70 (1.6) [60.7 (12.6)]	140
Midtrimester	6.55 (1.0) [48.1 (7.3)]	121
Third trimester	6.71 (1.2) [49.8 (8.9)]	160
1994–1998		
First trimester	7.38 (1.1) [57.2 (8.5)]	169
Midtrimester	6.41 (0.9) [46.6 (6.5)]	154
Third trimester	6.74 (0.9) [50.2 (6.7)]	184
1999–2003		
First trimester	7.64 (1.2) [60.0 (9.4)]	169
Midtrimester	6.56 (0.8) [48.2 (5.9)]	162
Third trimester	6.91 (1.1) [52.0 (8.3)]	186
2004–2008		
First trimester	7.59 (1.2) [59.5 (9.4)]	306
Midtrimester	6.68 (0.8) [49.5 (5.9)]	260
Third trimester	6.94 (0.9) [52.4 (6.8)]	317

The mean HbA_{1c} is expressed as a percentage, with the figure in mmol/mol in square brackets

p for trend 1989–2008: first trimester, 0.91; midtrimester, 0.009; third trimester, 0.005

Umbilical artery pH at birth The 20 year trend of the mean UA pH decreased among the infants of type 1 diabetic women with a vaginal delivery (p for trend <0.001). The trend of UA pH also decreased among pregnant women with a normal BMI (p for trend <0.001), but not among overweight or obese pregnant women. The percentages of newborn infants with a UA pH <7.05 or <7.15 increased during 1989–2008 (Table 4). Nulliparity and the last HbA_{1c} value before delivery, but not maternal BMI, were associated with a UA pH <7.15 (Table 3). In linear regression analysis, the last HbA_{1c} value before delivery correlated negatively with UA pH when adjusted for maternal age, BMI and parity (r=−0.13, p<0.001).

Apgar scores No significant change was observed in the percentage of infants with a 1 min (Table 4) or 5 min Apgar score <7 during the 20-year period (data not shown). Nor was there a difference in the frequency of Apgar scores <7 between the newborn infants of normal weight and obese type 1 diabetic patients. In multiple logistic regression analysis, nulliparity and the last HbA_{1c} value before delivery were associated with 1 min Apgar scores <7 (Table 3). Maternal BMI was not associated with Apgar scores <7 in univariate or multivariate logistic regression analyses (Table 3).

Relative birthweight Fetal macrosomia remained at a high level of 32–40% throughout the study period (Table 4). There was no difference in the incidence of macrosomia among the infants of normal weight and obese type 1 diabetic patients. In multiple logistic regression analysis, maternal BMI and the last HbA_{1c} before delivery were associated positively, and nulliparity and smoking negatively, with macrosomia (Table 3).

NICU admission The NICU admission rate increased during 1989–2008 (Table 4). The last HbA_{1c} before

Table 3 Maternal factors predicting adverse perinatal outcomes in 881 type 1 diabetic patients who delivered at HUCH in 1989–2008

Perinatal outcome	Maternal variable	Non-adjusted OR (95% CI)	Adjusted OR (95% CI)
Delivery before 37 weeks	Pre-eclampsia	3.66 (2.50, 5.36)	3.37 (2.23, 5.09)
	Last HbA_{1c} before delivery (%)	1.91 (1.63, 2.23)	1.80 (1.51, 2.14)
Umbilical artery pH <7.15	Nulliparity	1.59 (1.01, 2.53)	2.11 (1.28, 3.46)
	Last HbA_{1c} before delivery (%)	1.24 (1.00, 1.55)	1.27 (1.01, 1.61)
1 min Apgar score <7	Nulliparity	2.56 (1.63, 4.03)	2.94 (1.63, 5.33)
	Last HbA_{1c} before delivery (%)	1.53 (1.23, 1.90)	1.57 (1.22, 2.03)
Macrosomia (birthweight *z* score >2 SD units)	Last HbA_{1c} before delivery (%)	1.60 (1.38, 1.86)	1.64 (1.41, 1.92)
	BMI (kg/m^2)	1.06 (1.02, 1.11)	1.05 (1.00, 1.09)
	Nulliparity	0.51 (0.38, 0.68)	0.52 (0.38, 0.71)
	Smoking	0.57 (0.37, 0.88)	0.41 (0.26, 0.66)
NICU admission	Pre-eclampsia	2.36 (1.53, 3.62)	2.15 (1.33, 3.49)
	Last HbA_{1c} before delivery (%)	1.66 (1.39, 1.98)	1.59 (1.29, 1.95)
	BMI (kg/m^2)	1.08 (1.03, 1.13)	1.07 (1.01, 1.13)
Hypoglycaemia (plasma glucose <2.6 mmol/l)	Last HbA_{1c} before delivery (%)	1.58 (1.36, 1.83)	1.53 (1.31, 1.79)

Independent variables used in the multiple logistic regression analyses: maternal age, BMI, nulliparity, smoking, last HbA_{1c} before delivery, and pre-eclampsia; all variables with p<0.2 in the univariate analyses were entered into the multiple model

For continuous variables, non-adjusted and adjusted OR are presented per increment

Table 4 Trends in perinatal outcomes among the offspring of type 1 diabetic women who delivered at HUCH in 1989–2008

Outcome	1989–1993 (n=172)	1994–1998 (n=190)	1999–2003 (n=190)	2004–2008 (n=329)	p for trend
Gestational age (days) (IQR)	263 (256–267)	259 (248–265)	258 (250–263)	261 (255–267)	0.49
Delivery before 32 weeks' gestation	9 (5.2)	14 (7.4)	13 (6.8)	6 (1.8)	0.03
Delivery before 37 weeks' gestation	50 (29.1)	91 (47.9)	103 (54.2)	128 (38.9)	0.16
Birthweight z score (SD units)	1.25 (1.8)	1.58 (2.0)	1.34 (1.8)	1.42 (1.7) [328]	0.68
Birthweight z score >1.28 SD units (>90th percentile)	83 (48.3)	106 (55.8)	101 (53.2)	171 (52.1) [328]	0.68
Birthweight z score >2.0 SD units (>97.7th percentile)	58 (33.7)	75 (39.5)	61 (32.1)	110 (33.5) [328]	0.54
Birthweight z score <−2.0 SD units (<−2.3th percentile)	3 (1.7)	4 (2.1)	6 (3.2)	6 (1.8) [328]	0.93
Apgar score at 1 min <7	15 (8.7)	20 (10.5)	19 (10.0)	35 (10.7) [328]	0.57
Umbilical artery pH <7.05	0 (0) [170]	1 (0.5) [188]	4 (2.1) [188]	9 (2.8) [324]	0.008
Umbilical artery pH <7.15	6 (3.5) [170]	14 (7.4) [188]	11 (5.) [188]	49 (15.1) [324]	<0.001
NICU admission	16 (9.3)	36 (19.0) [189]	48 (25.3)	59 (18.0) [328]	0.03
Neonatal hypoglycaemia (plasma glucose <2.6 mmol/l)	109 (63.4)	106 (55.8)	108 (56.8)	157 (48.0) [327]	0.001

Values are means (SD), medians (interquartile range, IQR) or frequencies (%)

The number of subjects is presented in square brackets if different

delivery, maternal BMI and pre-eclampsia were associated with NICU admission (Table 3). As expected, delivery before 37 weeks' gestation was associated with NICU admission (non-adjusted OR 12.9; 95% CI 7.98, 20.69). Respiratory distress syndrome, transient tachypnoea/wet lung and hypoglycaemia were the three most common indications for NICU admission both in 1989–1993 and in 2004–2008. No significant differences were observed in any of the frequencies of the primary admission indications between the first and the last 5 year study periods.

Neonatal hypoglycaemia The frequency of neonatal hypoglycaemia decreased in 1989–2008 (Table 4). The infants of normal weight and obese mothers had a similar incidence of neonatal hypoglycaemia. In multiple logistic regression analysis, the last HbA_{1c} value measured before delivery was positively associated with the occurrence of neonatal hypoglycaemia (Table 3).

No differences were observed between the perinatal outcomes of male and female infants of type 1 diabetic patients during 1989–2008.

Discussion

This study shows that mothers with type 1 diabetes have gained weight in the past two decades along with the rest of the Finnish population [22]. During 1989–2008, glycaemic control in mid- and late pregnancy deteriorated, the number of elective CS deliveries decreased and emergency CS deliveries increased. Among newborn infants, fetal macrosomia persisted at a high level, UA pH at birth decreased and NICU admissions increased, whereas the frequency of neonatal hypoglycaemia decreased. During the same period, there were 26 perinatal deaths among the fetuses and infants of type 1 diabetic patients, which have been described previously by Teramo [21].

To our knowledge, this is the first study to investigate trends in prepregnancy BMI, glycaemic control and obstetric and perinatal outcomes among type 1 diabetic pregnant women in the past two decades. The sample size is large and population-based, and the study period of two decades enabled the analysis of temporal trends. A few changes in clinical practice during the study period, discussed below, might have influenced some of the results. The number of obstetric type 1 diabetic patients treated at HUCH increased markedly especially during the last 5 years of the study period. This may be related to the constantly increasing incidence of type 1 diabetes [1]. In addition, physicians' attitudes to women with type 1 diabetes becoming pregnant might have become more encouraging during the last two decades.

The increase in BMI during the last two decades shows that type 1 diabetic women have not escaped the worldwide obesity epidemic. Since patients commonly under-report weight and over-report height, the actual BMI levels might be even slightly higher, especially among overweight women [23]. On the other hand, the effect of under-reporting on BMI values has likely been relatively constant over the 20 year study period. Our observation is in line with the findings of Persson et al [11], who reported an increase in the prevalence of obesity from 13.2% in 1991–1997 to 18.4% in 1998–2003 among pregnant type 1 diabetic women in Sweden. Maternal overweight and obesity increase insulin resistance and insulin requirements in type 1 diabetic

women especially during the second half of pregnancy [24]. Thus, the increase in maternal BMI might have contributed at least to some extent to the deterioration in late pregnancy glycaemic control.

The importance of good glycaemic control in reducing fetal malformations and other pregnancy complications is well known [7, 15, 21, 25–27]. However, the glycaemic control of our type 1 diabetic patients in the first trimester did not improve between 1989 and 2008. Therefore, efforts should be made to increase attendance at prepregnancy clinics. The observation that poor glycaemic control in early pregnancy continues in late pregnancy is important and consistent with previous studies, which have shown that high HbA_{1c} values in early pregnancy are associated with adverse perinatal outcomes [28–30].

Although the observed increase in mean HbA_{1c} was moderate, the deterioration in glycaemic control was already evident by mid-pregnancy. Maternal hyperglycaemia increases the risk of fetal chronic hypoxia [21]. We and others have previously shown a positive correlation between late pregnancy HbA_{1c} values and amniotic fluid or cord blood erythropoietin (EPO) concentration as well as a negative correlation between amniotic fluid EPO levels and UA pH and pO_2 levels at birth [31–34]. The HbA_{1c} reflects the average glucose level over the preceding 6–8 weeks but does not give information on hyperglycaemic peaks. Hay [35] showed in late-gestation fetal sheep that constant, sustained hyperglycaemia combined with pulsatile hyperglycaemic peaks increases fetal insulin secretion, which in turn is associated with fetal macrosomia and chronic hypoxia. Moreover, it is possible that even a small increase in average glucose level over a prolonged period of time can have adverse effects on the fetus. Thus, one factor behind the observed decrease in UA pH at birth and increased NICU admissions could be the worsening of glycaemic control in the latter half of pregnancy. The avoidance of timely elective CS might also have contributed to the deterioration of these outcomes. Although poor glycaemic control is associated with an increased risk of pre-eclampsia [27], no increase in the incidence of pre-eclampsia was observed during the study period.

In recent years, the care of obstetric type 1 diabetic patients has changed at HUCH. Since 2006, a diabetes nurse has monitored the glycaemic control of type 1 diabetic patients, consulting the internist or obstetrician as needed. After 2006, only the most complicated type 1 diabetic cases have been referred to the internist in the department of obstetrics and gynaecology. The frequency of outpatient clinic visits has not changed. The reduced involvement of internists in the care of type 1 diabetic patients might have affected the glycaemic control of these patients. Another change in recent years has been the use of rapid-acting insulin analogues instead of human insulin. It is unlikely, however, that this could have resulted in the trend for increased HbA_{1c} since rapid-acting insulin analogues are equally effective [36].

A large population-based study from northern England recently reported improvements in glycaemic control and pregnancy outcomes among obstetric type 1 diabetic patients after amendments in the organisation and consistency of care as well as in region-wide audit and feedback practices [12]. Increased use of continuous glucose monitoring has been shown to improve second and third trimester glycaemic control in type 1 diabetic patients [37]. Our results indicate that a more intensive therapeutic approach, including timely increments in insulin dosages, should be adopted in type 1 diabetic patients throughout pregnancy.

The decrease in the elective CS rate likely reflects a change in the management of type 1 diabetic pregnancies. The trend for increased prepregnancy BMI among type 1 diabetic patients might have partly encouraged the avoidance of elective CS, as obesity is a risk factor for surgical complications. Diabetes has been shown to further increase the already elevated risk of post-CS infections in obese pregnant women [38]. The concurrent increase in the emergency CS rate and the decreasing trend of mean UA pH in vaginal deliveries suggest failure to identify those high-risk type 1 diabetic patients for whom vaginal delivery might not have been the safest choice. In logistic regression analysis, nulliparity, in addition to poor glycaemic control, was associated with the risk of UA pH <7.15 and low Apgar score at birth. This could be due to a longer second stage of delivery among nulliparas. However, the length of the second stage was not recorded in the present study.

Available data for deciding between a policy of elective CS delivery versus expectant management in term diabetic pregnancies is insufficient [39]. In the UK, the National Institute for Health and Clinical Excellence recommends that pregnant type 1 diabetic patients without suspected macrosomia should be offered elective delivery through induction of labour or elective CS after 38 completed weeks [40]. Furthermore, a recent study from Sweden demonstrated a decreased risk of Apgar scores <7 at 5 min of age among the infants of type 1 diabetic patients who underwent elective CS at 38 weeks' gestation compared with those delivered at 39 weeks or later, regardless of the mode of delivery [41].

Maternal obesity is associated with an increased risk of fetal macrosomia [14], which was also seen in this study. The macrosomia rate remained high throughout the study period and is in agreement with other reports from Finland and Sweden [11, 42]. Persson et al [11] reported an increase in the rate of infants with relative birthweight ≥2.0 SD units from 27.6% in 1991–1997 to 35.0% in 1998–2003. In the present study it is likely that the increasing frequency of overweight among type 1 diabetic women, along with the worsening of glycaemic control in late pregnancy, contributed to the persisting high rate of fetal macrosomia.

The incidence of neonatal hypoglycaemia decreased during the study period, although the last HbA_{1c} before delivery increased. This is likely due to the improved care of newborn infants of type 1 diabetic patients, including active early feeding practices, frequent blood glucose measurements and prompt treatment. The decrease in neonatal hypoglycaemia did not, however, reduce NICU admissions.

Hypertensive complications did not explain the increase in NICU admissions, as the rates of pre-eclampsia and pregnancy-induced hypertension remained constant. Surfactant treatment for preterm infants was started at HUCH in 1991 and glucocorticoid administration to the mother in cases of threatened preterm delivery in 1992. Since August 2002, nasal continuous positive airway pressure treatment has been used in the neonatal monitoring ward, located within the labour and delivery unit. However, the above-mentioned changes are more likely to have reduced the NICU admission rate rather than increased it.

Despite the fact that maternal overweight may complicate the achievement of good glycaemic control during pregnancy, no clear association could be shown between maternal self-reported prepregnancy BMI and UA pH values, Apgar scores or neonatal hypoglycaemia frequency in this study. However, the positive association of maternal BMI with NICU admission is likely related to the increased frequency of macrosomia among the infants of overweight type 1 diabetic women.

In conclusion, the rising self-reported prepregnancy BMI among type 1 diabetic patients is not associated with the increase in frequency of emergency CS and the decrease in UA pH at birth observed in this study. However, poor glycaemic control seems to be associated with adverse perinatal outcomes. The results call for further investigations into the causes of these trends. In particular, efforts should be focused on improving care and follow-up throughout pregnancy, especially in patients with poor glycaemic control in early pregnancy.

Acknowledgements The authors would like to thank H. Puttonen (Department of Obstetrics and Gynaecology, Helsinki University Central Hospital, Helsinki, Finland) for her invaluable assistance in retrieving information from patient records and carrying out data entry.

Duality of interest The authors declare that there is no duality of interest associated with this manuscript.

Contribution statement MK participated in the study design, acquisition of data and data entry, prepared the database and carried out the statistical analyses. In addition, she prepared the first draft, and edited and finalised the manuscript. MN, MT, MAK and VH participated in the analysis and interpretation of data and critically reviewed drafts of the manuscript. VH also reviewed the statistical analyses. KT initiated and planned the study, participated in the acquisition of data and drafted and critically reviewed, commented on and edited various versions of the manuscript. All authors read and approved the final version of the manuscript.

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