Title of manuscript [Educational and health outcomes of children treated for type 1 diabetes: Scotland-wide record linkage study of 766,047 children]

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Short title [Type 1 diabetes and educational/health outcomes]

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ABSTRACT (227 words)

Objective

To determine the association between childhood type 1 diabetes and educational and health outcomes.

Research Design and Methods

Record linkage of nine Scotland-wide databases (diabetes register, dispensed prescriptions, maternity records, hospital admissions, death certificates, annual pupil census, school absences/exclusions, examinations, and unemployment) produced a cohort of 766,047 singleton children born in Scotland who attended Scottish schools between 2009 and 2013. We compared the health and education outcomes of schoolchildren on insulin with their peers, adjusting for potential confounders.

Results

The 3,330 (0.47%) children treated for type 1 diabetes were more likely to be admitted to hospital (IRR 3.97, 95% CI 3.79-4.16, p<0001), die (HR 3.84, 95% CI 1.98-7.43, p<0.001), be absent from school (OR 1.34, 95% CI 1.30-1.39, p<0.001) and have learning difficulties (OR 1.19, 95% CI 1.03-1.38, p<0.05). Among children with type 1 diabetes, higher mean HbA1c (particularly HbA1c in the highest quintile) was associated with greater absenteeism (IRR 1.75, 95% CI 1.56-1.96, p<0.001), increased school exclusion (IRR 2.82, 95% CI 1.14-6.98, p<0.05), poorer attainment (OR 3.52, 95% CI 1.72-7.18, p<0.05) and higher risk of unemployment (OR 2.01, 95% CI 1.05-3.85, p<0.05).

Conclusions

Children with type 1 diabetes fare worse than their peers in respect of education, as well as health, outcomes; especially if they have higher mean HbA1c. Interventions are required to minimise school absence and ensure that it does not affect educational attainment.

Keywords

type 1 diabetes; educational outcomes; health; population cohort; record linkage; prescribing

Key messages

What is the key question?

- Is the impact of childhood type 1 diabetes wider than adverse health outcomes?

What is the bottom line?

- Children with type 1 diabetes are more likely to be absent from school and have learning difficulties; and children who have higher mean HbA1c achieve lower attainment in exams and are more likely to be unemployed after leaving school.

Why read on?

- Ours is the first population wide study to evaluate the impact of childhood type 1 diabetes on a wide range of outcomes covering health, education and employment.

BACKGROUND

The onset of type 1 diabetes peaks between 10 and 14 years of age; (1-3) when the affected individuals are still at school. The UK has the fifth highest incidence of type 1 diabetes among children under 14 years of age (roughly 22 per 100,000) (4) and, of the 31,000 Scottish residents with type 1 diabetes, 12.5% are under 19 years of age (1).

Unsurprisingly, children with type 1 diabetes are at greater risk of hospitalisation (5,6) and death. (7,8) However, it has been suggested that the impact of the condition may extend into other aspects of life; including educational outcomes. Previous studies have reported neurocognitive sequelae (9-11) and increased absenteeism (12-17) but it is unclear whether these translate into poorer exam attainment with some studies observing poorer academic performance in children with diabetes (13,14,17-21) and others reporting no difference. (16,22-24)

This study linked, at individual-level, all relevant Scotland-wide administrative databases from the health and education sectors to undertake a large-scale, unselected, general population cohort study comparing a wide range of education and health outcomes in children treated for type 1 diabetes and their peers.

METHODS

Databases

We linked individual-level data from four Scotland-wide health databases, held by the Information Services Division (ISD) of the National Health Service, four Scotland-wide education databases, held by the Scottish Exchange of Educational Data (ScotXed) and the Scottish diabetes register held by NHS Tayside on behalf of the Scottish Government. The linkage methodology has been described in detail previously (25,26) and has been validated and shown to be 99% accurate for singleton births. (25)

The prescribing information system (PIS) collects information on all prescriptions dispensed to Scottish residents by community pharmacies or primary care. The Scottish Care Information Diabetes (SCI-Diabetes) register holds clinical and laboratory data pertaining to all individuals in Scotland diagnosed with diabetes including age of onset, HbA1c measurements and results of other investigations. The Scottish Morbidity Record (SMR) 02 maternity database collects data on maternal, obstetric and child factors. SMR01 and SMR04 record admissions to acute and psychiatric hospitals, including date of admission, and the National Records of Scotland collect data from death certificates, including date of death.

The pupil census is conducted annually by all local authority run primary, secondary and special schools across the whole of Scotland and provided demographic information for all of the children in the study cohort. Information collected by the pupil census also includes whether the child has a special educational need and its type. Absences and exclusions are collected prospectively and appended to the pupil census at the end of the school year. The Scottish

Qualifications Authority collects examination attainment data for all Scottish schoolchildren. The school leaver database collects information on the status of pupils six months after leaving school: paid/voluntary employment, higher/further education, training or unemployment.

Inclusion criteria, definitions and outcomes

The study cohort comprised all children who attended a primary, secondary or special school at some point between 2009 and 2013 inclusive. Therefore, some pupils attended and had data collected across all five years whilst others only had data pertaining to some of the years if they started or left a Scottish school during the study period. We excluded individuals whose age was recorded as <4 years or >19 years in the pupil census. For multiple births involving offspring of the same sex, it is not possible to be certain that the correct child has been linked; therefore, this study was restricted to singleton children. We used PIS data to ascertain type 1 diabetes; defined as insulin dispensed on at least one occasion over a school year. Children who were not prescribed insulin but were prescribed other medications used to treat diabetes (defined as British National Formulary subsection 6.1.2) such as metformin were excluded from the study as described previously. (26) We validated our case ascertainment by comparing cases identified using PIS encashed prescription data with confirmed cases on the SCI-Diabetes register which extracts data from clinical practice. Finally, among children with type 1 diabetes, we investigated associations between mean HbA1c and educational outcomes using HbA1c data from the SCI-Diabetes register. Mean HbA1c was derived for each pupil across each school year (to investigate associations with annual absences, exclusions and record of special educational need) and also across the full study period (to investigate associations with final attainment and subsequent unemployment). Mean HbA1c was then categorised into quintiles. Children with missing HbA1c measurements were excluded from the analyses.

We studied six educational outcomes. Data on annual number of days absent, annual number of episodes of exclusion (if any), any annual record of a special educational need, and type of special educational need were available for each separate school year within the time period for every child in our cohort. These outcomes were therefore analysed on an annual basis accounting for correlations between serial measurements on the same child. Final examination grades, and subsequent unemployment on leaving school were analysed as single overall end points for each child. Analyses of the latter two outcomes were restricted to the sub-group of pupils who left school during the study period. In addition, absence and exclusion data were only available for years 2009, 2010 and 2012.

Special educational need is defined as being unable to benefit fully from school education without help beyond that normally given to schoolchildren of the same age. We included special educational need attributed to intellectual disabilities, learning difficulties, dyslexia, language or speech disorder, physical, motor or sensory impairment, autistic spectrum disorder, social, emotional and behavioural difficulties, physical health conditions, and mental health conditions. A child could be recorded as having more than one type. Academic achievement across the last three years of secondary school (S4-S6) was derived from the number of examination grades attained at each level of the Scottish Credit Qualifications Framework (SCQF) (27) and converted into an ordinal variable: low, basic, broad/general, high. Leaver destination six months after leaving school was collapsed into a dichotomous variable of education/employment/training or unemployment. We studied two health outcomes: subsequent all-cause hospital admission and subsequent all-cause mortality. Data on acute and psychiatric hospital admissions and deaths were available until September 2014 providing a mean follow-up period of 4.3 years (maximum 5 years).

The pupil census provided data on the child's sex, age and ethnicity. Area socioeconomic deprivation was derived from postcode of residence using the Scottish Index of Multiple Deprivation (SIMD) 2012, and children were allocated to general population quintiles. SIMD is derived from 38 indicators across 7 domains (income, employment, health, housing, geographic access, crime and education, skills and training) using Census information collected on datazones of residence (median population 769). We included, as potential confounders, maternal and obstetric variables, previously shown to be associated with special educational need. (28-30) Retrospective linkage to SMR02 provided data on maternal age at delivery, parity, maternal smoking, gestation at delivery, mode of delivery and 5 minute Apgar score. We also derived sex-, gestation-specific birthweight centiles as a measure of intra-uterine growth.

Statistical analyses

The characteristics of children on insulin for type 1 diabetes were compared with their peers using chi square tests for categorical data and chi square tests for trend for ordinal data. Special educational need, absences and exclusions were recorded on an annual basis and were, therefore, analysed as yearly outcomes using generalised estimating equations (GEE) to adjust for correlations between repeated observations relating to the same pupil across different census years. The user-written QIC statistic was used to compare different correlation structures. The structure with the lowest trace QIC was selected as being the most appropriate. (31) Counts of the number of days absent per year and number of exclusions per year were modelled on an annual basis using univariate and multivariable longitudinal GEE analyses with a negative binomial distribution and log link function. The total number of possible attendances

recorded for each pupil in each school census year was used as an offset variable to adjust for exposure time for each pupil. Any record of special educational need in a given year was modelled using GEE analyses with a binomial distribution and logit link.

Univariate and multivariable logistic regression models (ordinal and binary) were used to investigate the relationships between type 1 diabetes and final attainment and subsequent unemployment after leaving school respectively. Cox proportional hazard models were used to investigate the relationship between type 1 diabetes and time to hospital admission and death. These four longer-term end-outcomes were summarised and modelled on a pupil, rather than yearly, basis dependent on whether children had previously been prescribed insulin at any point within the study period. Therefore, repeated measures were not an issue and longitudinal methods were not required. In the Cox models, children prescribed insulin were followed from the date of their first insulin prescription in the period 2009 - 2013. The pupil census is recorded in September each year, a few weeks after the start of the school term. Therefore, children who did not receive insulin during the study period were instead followed from the approximate start date of their first school year within the study period; identified using their earliest pupil census date in the period. This methodology has been previously described. (26) Proportionality was tested using the *estat phtest* command within Stata and, where the assumption did not hold, a Poisson piecewise regression model was used. All multivariable models were run adjusting for sociodemographic and maternity confounders. We also explored age, sex and deprivation as potential effect modifiers. We tested for statistical interactions and, where significant, undertook sub-group analyses. All statistical analyses were undertaken using Stata MP version 14.1

Approvals

The study was approved by the National Health Service National Services Scotland Privacy Advisory Committee. A data processing agreement was drafted between Glasgow University and ISD and a data sharing agreement between Glasgow University and ScotXed. NHS Caldecott approval was additionally sought to link diabetes data to education records.

Ethics

The NHS West of Scotland Research Ethics Service confirmed that formal NHS ethics approval was not required since the study involved anonymised extracts of routinely collected data with an acceptably negligible risk of identification

RESULTS

Between 2009 and 2013, 766,244 singleton children born in Scotland attended Scottish schools; of these, 197 (0.03%) received diabetes medication other than insulin and were, therefore, excluded from the study. Of the 766,047 children included in the study, 3,330 (0.47%) were classified as having type 1 diabetes according to our study definition. Children with type 1 diabetes were less likely to be Asian, were larger for their gestational age at birth, and their mothers were less likely to have smoked during pregnancy (Table 1). The mean number of observed school years per pupil was 3.65 (range 1 – 5 years); 89% of pupils with diabetes and 86% of pupils without diabetes had more than one school record, and 52.6% of pupils with diabetes and 46.5% of pupils without diabetes attended school in all five of the study years.

[Table 1]

The subgroup analyses of absence and exclusion included 702,018 children. Children with type 1 diabetes had more days absent from school on univariate analysis (IRR 1.42, 95% CI 1.36-1.47) and after adjusting for sociodemographic (IRR 1.31, 95% CI 1.27-1.36) and maternity (IRR 1.34, 95% CI 1.30-1.39) confounders. There were no significant interactions between diabetes and age (p=0.13), diabetes and sex (p=0.12) or diabetes and socioeconomic deprivation (p=0.19) in relation to absenteeism in the multivariate analyses. Therefore the effect sizes were comparable for different ages, both sexes and each deprivation quintile. Among the sub-group of children with type 1 diabetes, those whose mean HbA1c was in the highest quintile were more likely to be absent from school (IRR 1.75, 95% CI 1.56-1.96, p<0001) (Table 2). Type 1 diabetes, per se, was not associated with exclusion from school on univariate analysis (IRR 0.97, 95% CI 0.78-1.22) or after adjusting for sociodemographic and maternity (IRR 0.89, 95% CI 0.71-1.11) factors. However, among children with type 1 diabetes, those whose mean HbA1c was in the highest quintile were more likely to be excluded (IRR 2.82, 95% CI 1.14-6.98, p<0.05)) from school (Table 2).

[Table 2]

Children with type 1 diabetes were more likely to have a record of special educational need on univariate analysis (OR 2.36, 95% CI 2.19-2.55) and after adjusting for sociodemographic (OR 2.36, 95% CI 2.18-2.55) and maternity (OR 2.45, 95% CI 2.26-2.66) factors. (Figure 1). There were significant interactions between diabetes and sex (p<0.001), diabetes and age (p<0.001) and diabetes and deprivation (p=0.043) in relation to special educational need in the multivariate analyses. The association between diabetes and special educational need was

stronger in girls (OR 3.00, 95% CI 2.66-3.38, p<0.001) than boys (OR 2.12, 95% 1.90-2.36, p<0.001) and among children aged under 11 years (OR 3.73, 95% CI 3.28-4.23, p<0.001). The association was also stronger in the least deprived quintile (fully adjusted OR 2.95, 95% CI 2.42-3.60) than the most (fully adjusted OR 2.17, 95% CI 1.83-2.56). However, this was due to special educational need, among children without type 1 diabetes, already being higher in deprived areas. Among children without type 1 diabetes, 19.7% of the most deprived quintile had a special education need compared with 10.4% of the least deprived. Among children taking insulin, special education need was still more common in the most deprived quintile than the least: 35.1% versus 26.7% respectively. The significant associations between type 1 diabetes and special educational needs were specific to: learning difficulties (adjusted OR 1.19, 95% CI 1.03-1.38, p<0.05), physical motor disabilities (adjusted OR 1.55, 95% CI 1.13-2.12, p<0.01) and physical health conditions (adjusted OR 24.08, 95% CI 21.83-26.57, p<0.001).

The subgroup analyses of 139,131 children who sat exams over the study period revealed no significant associations overall between type 1 diabetes and academic attainment on univariate analysis (OR 0.70, 95% CI 0.48-1.01) or after adjusting for sociodemographic (OR 1.04, 95% CI 0.91-1.21) and maternity (OR 1.14, 95% CI 0.99 -1.31) factors. However, among children with type 1 diabetes, those with HbA1c in the highest quintile had poorer attainment (IRR 3.52, 95% CI 1.72-7.18, p<0.05) (Table 2).

In the analyses of unemployment, conducted on a sub-group of 217,805 children, those with type 1 diabetes were no more likely to leave school before 16 years of age when compared to their peers (27.82% versus 28.81% respectively, p=0.425). Similarly, type 1 diabetes, per se, was not associated with unemployment on univariate analysis (OR 1.09, 95% CI 0.92-1.29) or after adjusting for sociodemographic (OR 1.13, 95% CI 0.94-1.34) and maternity (OR 1.18,

95% CI 0.99-1.41) factors. However, among children with type 1 diabetes, those with a mean HbA1c in the highest quintile were more likely to be unemployed (IRR 2.01, 95% CI 1.05-3.85, p<0.05)) after leaving school compared to children with type 1 diabetes whose mean HbA1c was in the lowest quintile (Table 2)

Linkage to hospital records provided 2.94 million person years of follow-up; with 157,294 pupils experiencing a total of 305,580 hospital admissions. In the Cox proportional hazards models, children with type 1 diabetes were at increased risk of being admitted to hospital for any cause (adjusted HR 3.97, 95% CI 3.79-4.16). However, the assumption of proportionality was not met (p<0.001). Therefore, Poisson piecewise regression models were run by period of follow-up and by age of child. In both cases there was a significant interaction with sex (p<0.001) whereby the association between type 1 diabetes and hospitalisation was stronger for boys than girls. Figures 2a and 2b show the fully adjusted incidence rate ratios for all-cause hospitalisation for boys and girls by year of follow-up and age at admission. Children with type 1 diabetes were more likely to be hospitalised over the whole follow-up period and irrespective of age. However, the magnitude of the association was greatest in the first year after treatment overall (IRR 4.43, 95% CI 4.13-4.75, p<0001) and among boys (IRR 4.10, 95% CI 3.70-4.53, p<0001) and girls (IRR 4.91, 95% CI 4.45-5.42, p<0001) and fell over time. Similarly the magnitude of the association was greatest among children aged between 11 and 12 years overall (IRR 5.25, 95% CI 4.67-5.91, p<0001) and among boys (IRR 4.49, 95% CI 3.78-5.33, p<0001) and girls (IRR 6.21, 95% CI 5.28-7.31, p<0001).

The total number of deaths were low (n=490). However, children with type 1 diabetes were significantly more likely to die over follow-up, on univariate analysis (HR 3.73, 95% CI 1.93-

7.22) and following adjustment for sociodemographic (HR 3.71, 95% CI 1.92-7.19) and maternity (HR 3.84, 95% CI 1.98-7.43) factors.

DISCUSSION

Consistent with previous literature, our study confirmed that children with type 1 diabetes were at increased risk of hospitalisation and mortality. (5,8) The risk of hospital admission was increased most within one year of starting insulin; when children are being stabilised on medication and learning how to manage their condition. Risk was increased most between 9 and 14 years of age, especially in girls, which may reflect the disruptive effects of puberty. (32)

Consistent with previous studies, (12-17) we demonstrated that children with type 1 diabetes experience more frequent authorised and unauthorised absence from school. We also found they were more likely to have a record of learning difficulty. This is consistent with previous findings of increased risk of neurocognitive impairment. (9-11) The association with special educational need was greater in girls and children under 11 years of age. The latter is consistent with previous evidence that the negative impact of diabetes on cognition is greatest when a diagnosis occurs before 7 years of age. (9,18,20)

The higher risk of absenteeism among all children with type 1 diabetes, compared to peers, did not translate into poorer performance in exams. However, children with higher mean HbA1c did fare worse in exams, as shown previously, (33) and also future employment. It is unclear whether the higher risk of exclusion from school associated with higher mean HbA1c reflects a causative link or possible behavioural issues and justifies further research.

A number of studies have demonstrated associations between diabetes and measures potentially influencing educational outcomes. Previous studies have reported adverse effects of diabetes on IQ, (10) spelling, reading and arithmetic, (14,33) spatial and verbal intelligence, (34) memory (9,35) attention (13,35) and behaviour. (16) Deficits among children with diabetes have been reported in meta-analyses across most cognitive domains. (9-11) The mechanisms underpinning these associations are less clear but are likely to involve both direct and indirect factors. Compromised brain function is thought to arise through continual exposure to fluctuating and abnormal levels of insulin and glucose within the vascular system (35). Children may experience acute or chronic neurocognitive effects. Both hypo- and hyperglycaemia could theoretically produce direct effects on acute cognition and behaviour including attention, memory and mood. Small vessel disease can also produce chronic neurocognitive sequelae – but the relevance of this to this age group, usually with relatively short disease duration, would need to be demonstrated. Type 1 diabetes as a chronic disease will also exert a physical and mental burden on affected schoolchildren who, compared to their peers, require daily insulin injections and need to continually monitor their diet, exercise and blood glucose whilst still trying to perform well at school. The child may feel different to his/her peers and both the child and parents may feel anxious about the management and long-term implications of the condition. (36,37) For some children, this may even result in depression. (38) To that end HbA1c may be acting as a marker of the ability of a child and their family to adjust to and cope with chronic disease. Finally, diabetes may impact on school absence (12-17) because of episodes of hyper- and hypoglycaemia or diabetic ketoacidosis, and planned or emergency healthcare attendances. (5,6) Although it is notable that the higher risk of absenteeism among all children with type 1 diabetes, compared to peers, did not translate into poorer performance in exams.

This was the largest study, to date, to evaluate the educational and health outcomes of children who have type 1 diabetes. Previous studies have generally been limited by the use of an unrepresentative hospital cohort or the absence of a comparison group. Ours was a large, non-selective study that included children across the whole of Scotland. Because the sampling frame was all mainstream and special schools in Scotland, rather than hospital clinics, inclusion was not restricted to the most severe diabetes cases. To our knowledge, only one Swedish study has previously investigated educational outcomes on a national level. (18) Few have investigated school grades (18-20,22) focussing instead on more subjective parent, (12) teacher (13) or individual (23,24,39) reported outcomes. The only two previous UK studies, to our knowledge, were limited by small sample size and poor study design. (23,24)

We were able to adjust for a range of potential confounders: sociodemographic, obstetric and maternal. The large study size provided sufficient power to test for statistical interactions and undertake sub-group analyses where appropriate. We were able to analyse a wide range of outcomes in the same study covering both the educational and health sectors. No previous studies have investigated as wide a range of outcomes. The definition of type 1 diabetes used in this study was the requirement for children to have been dispensed insulin at any point during the school year. Children who have type 1 diabetes need insulin to survive; therefore, case ascertainment should be complete and accurate. Nevertheless, we validated our case ascertainment by comparing the PIS encashed prescription data and SCI-Diabetes register data and found that 96.3% of children identified via PIS as receiving insulin also had a formal diagnosis of type 1 diabetes recorded in the SCI-Diabetes register. SCI-Diabetes is a clinically used system which is scrutinised and amended by clinicians during consultations.

The study only included children attending local authority maintained schools; however, in Scotland, less than 5% of children attend private schools. According to the 2011 Scottish Census, 11% of Scottish residents aged 5-19 years were born outside of Scotland; this is consistent with the 12% of children attending school in Scotland who could not be linked to Scottish maternity records in our study. The prevalence of insulin use was slightly lower (0.32%) in pupils who could not be linked compared to those who could (0.44%). The reasons for this are unknown but one explanation may be the lower incidence of type1 diabetes in other parts of the UK. (40) Our overall observed type 1 diabetes prevalence of 0.43% was comparable with the 0.39% reported by a similar population-wide study conducted in Sweden. [18] Our study used existing, administrative databases established for other purposes. However, they undergo regular quality assurance checks. The linkage of education and health records relied on probabilistic matching. A previous validation study demonstrated that this method was 99% accurate for singletons. (25)

CONCLUSION

Children who have type 1 diabetes have poorer health outcomes but also experience worse educational outcomes particularly if they have higher mean HbA1c. Interventions are required to try to minimise school absence, and obviate any adverse effect of absences when they occur.

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AUTHOR CONTRIBUTIONS

JPP had the original concept. All authors agreed the study design. DC and AK provided data and undertook record linkage. MF and DFM undertook the statistical analyses. All authors interpreted the results. MF and JPP drafted the manuscript and all other authors contributed revisions. All authors reviewed and approved the final version of the manuscript. MF is guarantor for the study.

DECLARATION OF INTERESTS

All authors declare no competing interests.

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Table 1. Characteristics of schoolchildren by presence or not of type 1 diabetes

		No type 1 diabetes N=762,717		Type 1 diabetes N=3,330		
		N	%	N	%	P value
Sociodemographic factors						
Sex						
	Male	388,517	50.9	1,720	51.7	0.411
	Female	374,200	49.1	1,610	48.3	
	Missing	0		0		
Deprivation quintile						
	1 (most deprived)	173,073	22.7	669	20.1	0.096
	2	152,783	20	736	22.1	
	3	147,241	19.3	645	19.4	
	4	148,836	19.5	660	19.8	
	5 (least deprived)	140,192	18.4	619	18.6	
	Missing	592		1		
Ethnic group						
	White	724,695	96.2	3,244	98.3	<0.001
	Asian	17,730	2.4	29	0.9	
	Black	1,965	0.3	0	0	
	Mixed	6,702	0.9	25	0.8	
	Other	2,073	0.3	3	0.1	
	Missing	9,552		29		
Maternity factors						
Maternal age (years)						
	≤24	208,992	27.4	835	25.1	0.373
	25-29	223,425	29.3	1,056	31.7	
	30-34	215,915	28.3	961	28.9	
	≥35	114,373	15	478	14.4	
	Missing	12		0		
Maternal smoking						
	No	488,740	72.3	2,252	77	<0.001
	Yes	187,064	27.7	671	23	
	Missing	86,913		407		
Parity						
	0	344,044	45.3	1,528	46.1	0.639
	1	262,957	34.7	1,118	33.7	
	>1	151,865	20	668	20.2	
	Missing	3,851		16		
Mode of delivery						
	SVD	513,860	67.3	2,238	67.3	0.512
	Assisted vaginal	91,212	12	427	12.8	
	Breech vaginal	2,223	0.3	8	0.2	
	Elective CS	58,025	7.6	262	7.9	
	Emergency CS	97,233	12.7	394	11.8	
	Other	162	0	1	0	

	Missing	2		0		
Gestation (weeks)						
	<24	29	0	0	0	0.061
	24-27	1,121	0.1	3	0.1	
	28-32	7,026	0.9	32	1	
	33-36	35,426	4.6	164	4.9	
	37	37,417	4.9	183	5.5	
	38	95,503	12.5	466	14	
	39	158,056	20.7	646	19.4	
	40	229,320	30.1	1,045	31.4	
	41	170,485	22.4	671	20.2	
	42	27,010	3.5	112	3.4	
	43	627	0.1	3	0.1	
	>43	138	0.0	2	0.1	
	Missing	559		3		
Sex-gestation-specific birthweight centile						
	1-3	31,362	4.1	107	3.2	<0.001
	4-10	68,376	9.0	254	7.6	
	11-20	90,978	11.9	344	10.3	
	21-80	448,020	58.8	1,992	59.9	
	81-90	65,036	8.5	311	9.4	
	91-97	40,986	5.4	226	6.8	
	98-100	16,984	2.2	91	2.7	
	Missing	975		5		
5 minute Apgar						
	1-3	3,687	0.5	21	0.6	0.483
	4-6	7,273	1.0	29	0.9	
	7-10	743,960	98.5	3,256	98.5	
	Missing	7,797		24		

N number; SVD spontaneous vaginal delivery; CS Caesarean section

Table 2. Association between HbA1c and educational outcomes: absenteeism, exclusion, attainment and unemployment

	Absence		Exclusion		Attainment		Unemployment	
	IRR	95% CI	IRR	95% CI	OR	95% CI	OR	95% CI
Quintile 2	1.06	0.95-1.18	1.17	0.45-3.01	1.01	0.46-2.21	1.14	0.54-2.38
Quintile 3	1.23**	1.11-1.39	1.14	0.39-3.34	2.09*	1.01-4.32	1.11	0.55-2.25
Quintile 4	1.39**	1.23-1.56	2.75*	1.06-7.11	2.98*	1.45-6.10	2.10*	1.09-4.08
Quintile 5	1.75**	1.56-1.96	2.82*	1.14-6.98	3.52*	1.72-7.18	2.01*	1.05-3.85

Quintile 1 [% (mmol/mol)]: range [4.9% (30) - 7.7% (61)]; mean [7.2% (55)]; median [7.3% (56)]
Quintile 2 [% (mmol/mol)]: range [7.7% (61) - 8.4% (68)]; mean [8.1% (65)]; median [8.1% (65)]
Quintile 3 [% (mmol/mol)]: range [8.4% (68.) - 9.0% (75)]; mean [8.7% (71)]; median [8.7% (71)]
Quintile 4 [% (mmol/mol)]: range [9.0% (75) - 9.8% (84)]; mean [9.4% (79)]; median [9.3% (79)]
Quintile 5 [% (mmol/mol)]: range [9.8% (84) - 9.8% (173)]; mean [11.1% (98)]; median [10.7% (94)]

All models adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- gestation-specific birthweight centile and 5-minute Apgar score

IRR incidence rate ratio; OR odds ratio; CI confidence interval

* $p<0.05$; ** $p<0.001$

Figure 1 - Forest plot of the association between treatment for diabetes and special educational need by sex, age and area deprivation.

adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- gestation-specific birthweight centile and 5 minute Apgar score

SIMD – Scottish Index of Multiple Deprivation

Figure 2 Poisson regression model of the risk of hospitalisation over five years follow-up from first record of treatment.

a. by time from diagnosis and sex (boys=solid square; girls=hollow diamond)

b. by age at admission and sex (boys=solid square; girls=hollow diamond)

adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- gestation-specific birthweight centile and 5 minute Apgar score

SIMD – Scottish Index of Multiple Deprivation