Educational and Health Outcomes of Children Treated for Type 1 Diabetes: Scotland-Wide Record Linkage Study of 766,047 Children

https://doi.org/10.2337/dc18-2423

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EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

OBJECTIVE

This study was conducted 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, school 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 receiving insulin with their peers, adjusting for potential confounders.

RESULTS

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

CONCLUSIONS

Children with type 1 diabetes fare worse than their peers in respect of education and health outcomes, especially if they have higher mean HbA_{1c}. Interventions are required to minimize school absence and ensure that it does not affect educational attainment.

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 U.K. has the fifth highest incidence of type 1 diabetes among children <14 years of age (~22 per 100,000) (4), and of the 31,000 Scottish residents with type 1 diabetes, 12.5% are <19 years of age (1).

Unsurprisingly, children with type 1 diabetes are at greater risk of hospitalization (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

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Received 25 November 2018 and accepted 17 June 2019

Diabetes Care Publish Ahead of Print, published online July 15, 2019

studies have reported neurocognitive sequelae (9–11) and increased absenteeism (12–17), but whether these translate into poorer examination attainment is unclear, 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 the 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.

RESEARCH DESIGN AND 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 (NHS), 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, HbA_{1c} 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 collects 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 6 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 5 years, whereas 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 subject ascertainment by comparing case subjects identified using PIS encashed prescription data with confirmed case subjects on the SCI-Diabetes register, which extracts data from clinical practice.

Finally, among children with type 1 diabetes, we investigated associations between mean HbA_{1c} and educational outcomes using HbA_{1c} data from the SCI-Diabetes register. Mean HbA_{1c} 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 HbA_{1c} was then categorized into quintiles. Children with missing HbA_{1c} 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 analyzed annually, accounting for correlations between serial measurements on the same child. Final examination grades and subsequent unemployment on leaving school were analyzed as single overall end points for each child. Analyses of the latter two outcomes were restricted to the subgroup 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 behavioral difficulties, physical health conditions, and mental health conditions. A child could be recorded as having more than one type. Academic achievement across the last 3 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. This was recategorized as low/basic, broad/general, high to investigate the association between HbA_{1c} and attainment among the subgroup of children with type 1 diabetes. Leaver destination 6 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

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					
Vaginal delivery					
Spontaneous	513,860	67.3	2,238	67.3	0.512
Assisted	91,212	12	427	12.8	
Breech	2,223	0.3	8	0.2	
Caesarean section					
Elective	58,025	7.6	262	7.9	
Emergency	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		

Continued on p. 4

2012, and children were allocated to general population quintiles. Scottish Index of Multiple Deprivation 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 data zones 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-min Apgar score. We also derived sex- and gestation-specific birth weight centiles as a measure of intrauterine growth.

Statistical Analyses

The characteristics of children on insulin for type 1 diabetes were compared with their peers using χ^2 tests for categorical data and χ^2 tests for trend for ordinal data. Special educational need, absences, and exclusions were recorded annually and were therefore analyzed as yearly outcomes using generalized estimating equations (GEE) to adjust for correlations between repeated observations relating to the same pupil across different census years. The user-written QIC (Quasi-likelihood under the Independence Model Criterion) 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 modeled annually 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 modeled 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.

Table 1—Continued

	No type 1 diabetes		Type 1 diabetes		
	N = 762,717		*N* = 3,330		
	N	%	*N*	%	*P* value
Sex- and gestation-specific birth weight 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-min Apgar score					
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		

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 summarized and modeled 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 monitored 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 monitored 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 software, 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, performed subgroup analyses. All statistical analyses were undertaken using Stata MP 14.1 software.

Approvals

The study was approved by the NHS 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 because the study involved anonymized 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 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); 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 5 of the study years.

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 (incidence rate ratio [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) factors. 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 subgroup of children with type 1 diabetes, those whose mean HbA_{1c} was in the highest quintile were more likely to be absent from school (adjusted IRR 1.75, 95% CI 1.56–1.96) compared with children with type 1 diabetes whose mean HbA_{1c} was in the lowest quintile (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 HbA_{1c} was in the highest quintile were more likely to be excluded (adjusted IRR 2.82, 95% CI 1.14–6.98) from school compared with children with type 1 diabetes whose mean HbA_{1c} was in the lowest quintile (Table 2).

Children with type 1 diabetes were more likely to have a record of special educational need on univariate analysis (odds ratio [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 (Fig. 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 (adjusted OR 3.00, 95% CI 2.66–3.38) than in boys (adjusted OR 2.12, 95% 1.90–2.36) and among children aged <11 years (adjusted OR 3.73, 95% CI 3.28–4.23). The association was also stronger in the least-deprived quintile (adjusted OR 2.95, 95% CI 2.42–3.60) than in the most (adjusted OR 2.17, 95% CI 1.83–2.56). However, this was due to special educational need, among

Table 2—Association between HbA_{1c} and educational outcomes: absenteeism, exclusion, attainment, and unemployment

	Absence		Exclusion		Low/Basic 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 HbA_{1c} data here are shown as % (mmol/mol). Quintile 1: range 4.9 –7.7% (30–61); mean 7.2% (55); median 7.3% (56). Quintile 2: range 7.7–8.4% (61–68); mean 8.1% (65); median 8.1% (65). Quintile 3: range 8.4–9.0% (68–75); mean 8.6% (71); median 8.6% (71). Quintile 4: range 9.0–9.8% (75–84); mean 9.4% (79); median 9.4% (79). Quintile 5: range 9.8–18.0% (84–173); mean 11.1% (98); median 10.8% (94). All models adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- and gestation-specific birth weight centile, and 5-min Apgar score. *$P < 0.05$; **$P < 0.001$.

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 in the least: 35.1% vs. 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), physical motor disabilities (adjusted OR 1.55, 95% CI 1.13–2.12), and physical health conditions (adjusted OR 24.08, 95% CI 21.83–26.57).

The subgroup analyses of 139,131 children who sat examinations during 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 HbA_{1c} in the highest quintile were more likely to achieve a low/basic level of academic attainment (adjusted OR 3.52, 95% CI 1.72–7.18) compared with children with type 1 diabetes whose mean HbA_{1c} was in the lowest quintile (Table 2).

In the analyses of unemployment, conducted on a subgroup of 217,805 children, those with type 1 diabetes were no more likely to leave school before 16 years of age compared with their peers (27.82% vs. 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 HbA_{1c} in the highest quintile were more likely to be unemployed (adjusted OR 2.01, 95% CI 1.05–3.85) after leaving school compared with children with type 1 diabetes whose mean HbA_{1c} 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 305,580 hospital admissions. In the Cox proportional hazards models, children with type 1 diabetes were at increased risk of being admitted to the hospital for any cause (adjusted hazard ratio [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 hospitalization was stronger for boys than for girls. Figure 2 shows the fully adjusted IRRs for all-cause hospitalization for boys and girls by year of follow-up and age at admission. Children with type 1 diabetes were more likely to be hospitalized during the whole follow-up period and irrespective of age. However, the magnitude of the association was greatest in the 1st year after treatment overall (adjusted IRR 4.43, 95% CI 4.13–4.75) and among boys (adjusted IRR 4.10, 95% CI 3.70–4.53) and girls (adjusted IRR 4.91, 95% CI 4.45–5.42) and fell over time. Similarly the magnitude of the association was greatest among children aged between 11 and 12 years overall (adjusted IRR 5.25, 95% CI 4.67–5.91) and among boys (adjusted IRR 4.49, 95% CI 3.78–5.33) and girls (adjusted IRR 6.21, 95% CI 5.28–7.31).

The total number of deaths was low ($n = 490$). However, univariate analysis showed children with type 1 diabetes were significantly more likely to die over follow-up (HR 3.73, 95% CI 1.93–7.22)

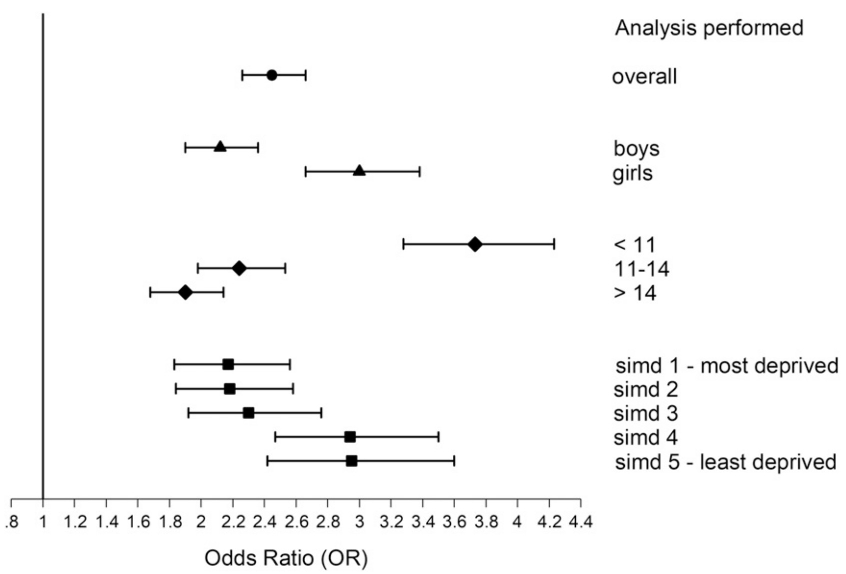

Figure 1—Forest plot of the association between treatment for diabetes and special educational need by sex, age, and area deprivation, adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- and gestation-specific birth weight centile, and 5-min Apgar score. SIMD, Scottish Index of Multiple Deprivation.

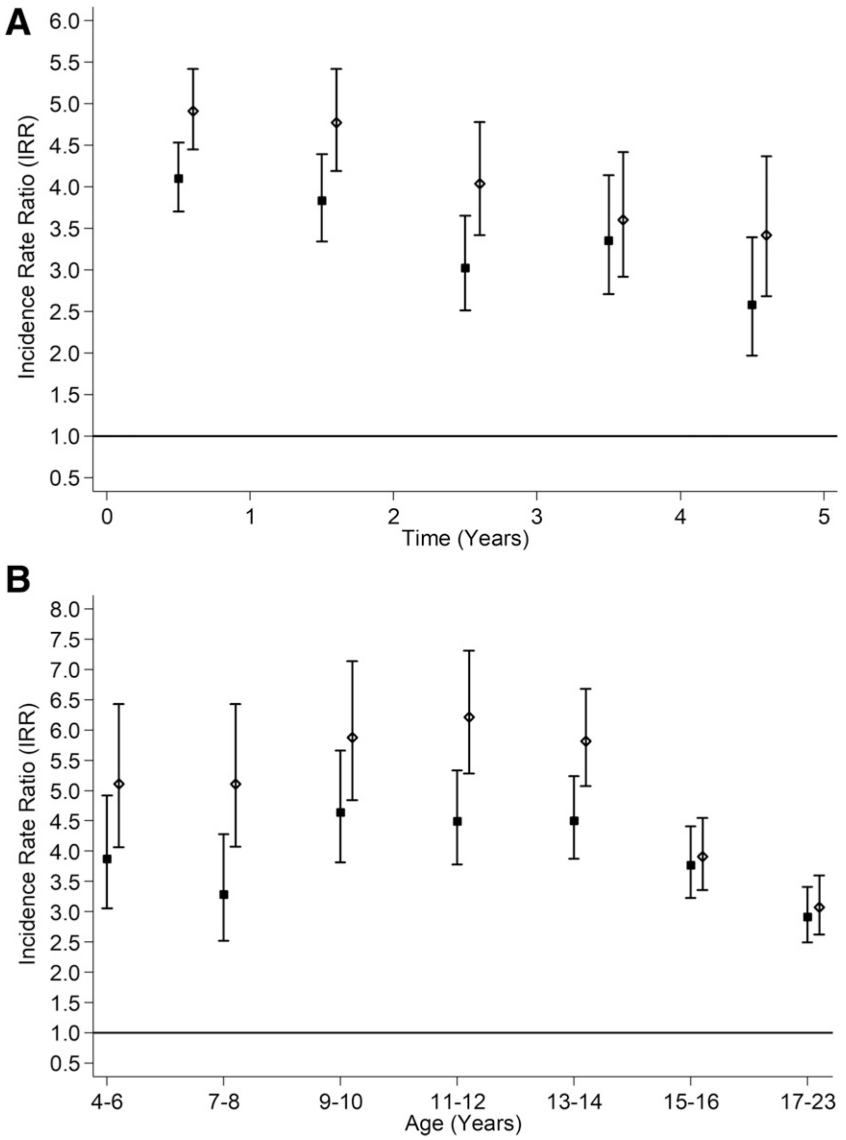

Figure 2—Poisson piecewise regression model of the risk of hospitalization over 5 years of follow-up from the first record of treatment by time from diagnosis and sex (*A*) and by age at admission and sex (■, boys; ◇, girls) (*B*), adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- and gestation-specific birth weight centile, and 5-min Apgar score.

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

CONCLUSIONS

Consistent with previous literature, our study confirmed that children with type 1 diabetes were at increased risk of hospitalization and mortality (5,8). The risk of hospital admission was increased most within 1 year of starting insulin, when children are being stabilized 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 authorized and unauthorized 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 <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 with peers, did not translate into poorer performance in examinations. However, children with a higher mean HbA_{1c} did fare worse in examinations, as shown previously (33), and also future employment. Whether the higher risk of exclusion from school associated with higher mean HbA_{1c} reflects a causative link or possible behavioral issues is unclear 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 the intelligence quotient (10), spelling, reading, arithmetic (14,33), spatial and verbal intelligence (34), memory (9,35), attention (13,35), and behavior (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. Hypo- and hyperglycemia could both theoretically produce direct effects on acute cognition and behavior, 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 with their peers, require daily insulin injections and need to continually monitor their diet, exercise, and blood glucose while still trying to perform well at school. The child may feel different from his or her peers, and the child and parents may both 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, HbA_{1c} may be acting as a marker of the ability of a child and his or her family to adjust to and cope with chronic disease.

Finally, diabetes may affect school absence (12–17) because of episodes of hyper- and hypoglycemia or diabetic ketoacidosis and planned or emergency health care attendances (5,6). Although it is notable that the higher risk of absenteeism among all children with type 1 diabetes, compared with peers, did not translate into poorer performance in examinations.

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, nonselective 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), focusing instead on more subjective outcomes reported by parents (12), teachers (13), or individuals (21,23,24). The only two previous U.K. 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 sociodemographic, obstetric, and maternal confounders. The large study size provided sufficient power to test for statistical interactions and undertake subgroup analyses where appropriate. We were able to analyze 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 that is scrutinized and amended by clinicians during consultations.

The study only included children attending local authority–maintained schools; however, $<$5% of children in Scotland 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 with those who could (0.44%). The reasons for this are unknown, but one explanation may be the lower incidence of type 1 diabetes in other parts of the U.K. (39). 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 HbA_{1c}. Interventions are required to try to minimize school absence and obviate any adverse effect of absences when they occur.

Acknowledgments. This study formed part of a wider PhD thesis undertaken by M.F. within the University of Glasgow, which was published in 2017. Therefore, certain sections of this manuscript appear in the thesis, which is accessible and downloadable from the following link: http://theses.gla.ac.uk/8594/1/2017flemingphd.pdf.

Funding. The study was sponsored by Health Data Research UK (www.hdruk.ac.uk) (grant reference number MR/S003800/1), which is a joint investment led by the Medical Research Council, together with the National Institute for Health Research (England), the Chief Scientist Office (Scotland), Health and Care Research Wales, Health and Social Care Research and Development Division (Public Health Agency, Northern Ireland), the Engineering and Physical Sciences Research Council, the Economic and Social Research Council, the British Heart Foundation, and Wellcome (grant reference number MR/S003800/1).

The sponsor and funders had no role in the design and conduct of the study, collection, management, analysis, and interpretation of the data, preparation, review, or approval of the manuscript, or decision to submit the manuscript for publication.

Duality of Interest. No potential conflicts of interest relevant to this article were reported.

Author Contributions. M.F., C.A.F., M.F.C.S., J.S.M., D.C., A.K., R.S.L., D.F.M., and J.P.P. agreed to the study design. All authors interpreted the results and reviewed and approved the final version of the manuscript. M.F. and D.F.M. undertook the statistical analyses. M.F. and J.P.P. drafted the manuscript, and all other authors contributed revisions. D.C. and A.K. provided data and undertook record linkage. J.P.P. had the original concept. M.F. is guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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