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ARTICLE

Impact of childhood-onset type 1 diabetes on schooling: a population-based register study

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Abstract

Aims/hypothesis We investigated the impact of type 1 diabetes on educational achievements in compulsory and upper secondary school, as well as potential long-lasting effects.

Methods Altogether 2,485 individuals with type 1 diabetes, diagnosed at the age of <15 years and born in 1972–1978, were selected from the Swedish Childhood Diabetes Register, which was linked to national population registers including the Swedish Education Register. For each individual, four controls from the general population, matched for year of birth and residence at the time of diagnosis, were selected by Statistics Sweden (n=9,940). We analysed the impact of diabetes on final school grades at 16 years (compulsory school) and 19 years (upper secondary school) and on participation in the labour market at 29 years using linear, logistic, ordered logistic and quantile regression analyses, controlling for demographics and socioeconomic background.

Results Diabetes had a negative effect on mean final grades (scale of 1–5) in compulsory school (−0.07, p<0.001) and theoretical programmes in upper secondary school (−0.07, p=0.001). Children with early-onset diabetes (0–4 years) suffered a greater disadvantage as a result of the disease (−0.15, p=0.001 in compulsory school). The strongest effect was seen in the lowest deciles of the conditional distribution on mean final grades. At age 29, individuals with diabetes were less likely to be gainfully employed (OR 0.82, 95% CI 0.73, 0.91).

Conclusions/interpretation The small but significant negative effect of type 1 diabetes on schooling could affect opportunities for further education and career development. Attention must be paid in school to the special needs of children with diabetes.

Keywords Education · Register study · Schooling · Type 1 diabetes

Abbreviation
SCDR The Swedish Childhood Diabetes Register

Introduction

The direct negative health effects of type 1 diabetes mellitus are well known. Less is known, however, about the socioeconomic consequences of the disease and how it affects ability to perform well in school and the labour market. The onset of diabetes in childhood requires several changes in a child's daily routines. Acute hypoglycaemic episodes will temporarily affect mental alertness, as will more long-lasting episodes of hyperglycaemia and ketoacidosis. The prospects of future long-term complications can psychologically affect children with diabetes, especially in their teens. These and other characteristics of type 1 diabetes may affect the sufferer's school achievements and ultimate level of education attained.

Evidence of the effect of childhood onset of type 1 diabetes on educational achievements is limited and often based on small study populations, lacking longitudinal data

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and without accounting for the impact of family socioeconomic status [1]. Two reviews on educational achievement found that type 1 diabetes has been associated with lower school achievements [1, 2]. Gaudieri et al [3] found that diabetes generally relates to slightly lower cognitive ability, and Hannonen et al [4] showed that children with early-onset diabetes are at higher risk of minor learning difficulties. A previous study from the Swedish Childhood Diabetes Study Group showed slightly lower final grades from compulsory school compared with non-diabetic children [5], but we found no studies analysing the potential cumulative impact of diabetes on later educational levels.

The aim of this study was to analyse the cumulative impact on educational achievement of childhood onset of type 1 diabetes, controlling for demographic and socioeconomic background. A further aim was to explore whether diabetes and educational achievement were associated with participation in the labour market among the young adults included 10 years after they had finished upper secondary school.

Methods

The impact of type 1 diabetes was analysed using individual-level data from national databases on diabetes incidence, school grades from compulsory and upper secondary school, and parental socioeconomic status. The Swedish Childhood Diabetes Register (SCDR) has recorded incident cases of type 1 diabetes in children aged 0–14.9 years in Sweden since 1 July 1977. The coverage has been estimated to be 96–99% [6], and, by 2007, the SCDR included 14,828 individuals [5]. Data for the SCDR were collected according to the Declaration of Helsinki, and informed consent was given by all parents of registered children.

Using patients' personal identification numbers, we linked the SCDR at the individual level to several nationwide registers and databases including the Longitudinal Integration Database for Health Insurance and Labour Market Studies (LISA) [7], the Multi-Generation Register [8] and the Swedish Register of Education at Statistics Sweden [9]. Record linkage was performed by Statistics Sweden, and only coded data were stored in the local database kept at Umeå University. The study was approved by the Regional Research Ethics Board in Umeå (Dnr 07-169M). Patients and their parents were given the opportunity to opt out of this specific study.

For each individual included from the SCDR, Statistics Sweden selected four non-diabetic individuals from the Register of the Total Population. These controls were matched for birth year and municipality of residence at the time of diabetes diagnosis. This method was used to create a manageable control group of non-diabetic children. The parents of the children with diabetes and the controls were identified through the Multi-Generation Register at Statistics Sweden.

Study population A total of 2,485 individuals from the SCDR and 9,940 controls, born during 1972–1978 and diagnosed during 1977–1993, were available in the dataset. People born during these years had the same numerical grading system in compulsory school. The analysis of final grades from upper secondary school was restricted to individuals born in 1972–1977, as the grading system changed in upper secondary school for those born from 1978 onwards.

Variables We analysed three measures of educational attainment: (1) the probability of completing compulsory and upper secondary school; (2) the mean final grade of all school subjects, from compulsory and upper secondary school; and (3) the compulsory school grades in the three core subjects, Swedish, English and mathematics, as well as in athletics. From 1962 to 1997, the grading system in Sweden was numerical using a 5-grade scale where 5 was the top grade. General entry requirements for a range of higher education programmes were a minimum of grade 3 in the core subjects, Swedish, Mathematics and English. The grading system was relative and designed to be normally distributed at the national level. Students were admitted to the next level of education on the basis of their mean final grade from the previous level, e.g. the mean final grade from compulsory school determined whether the application to upper secondary school would be successful. The more popular educational programmes required a mean final grade of ≥4. The outcome measure, school grades, should not be viewed as similar to actual ability or skills, as it can be influenced (upward or downward) by the teacher's subjective perceptions of a student with diabetes.

Diabetes was defined as a categorical variable with either two categories (non-diabetes/diabetes) or four categories according to age at diabetes onset (non-diabetes/diabetes with age at onset of 0–4, 5–9 and 10–15 years). Age at diagnosis was defined as year of diagnosis − year of birth. We controlled for demographic (year of grade, sex and whether the mother and/or father were born in a Nordic country [Denmark, Finland, Iceland, Norway or Sweden]) and socioeconomic (parents' level of education and long-term income) confounders in the analysis. Maternal and paternal education was categorised in three levels: low, 7–9 years of compulsory schooling (depending on birth year of the parent); medium, upper secondary education adding 2–4 years of schooling; and high, university education. According to the theory of permanent income, consumption patterns are determined by an individual's longer-term income expectations and not by current annual income [10]. Long-term income was defined as the mothers' and fathers' mean annual earnings, independently, during 1990–2007, deflated to the 2007 price level using the consumer price index. In the analyses of upper secondary education attainment, we also controlled for the final grade from compulsory school to isolate the effect pertaining to the upper secondary level.

Students could choose from about 20 programmes in upper secondary school. There were two types of programme: vocational programmes aiming at labour market entrance after graduation, and theoretical programmes in preparation for higher education in college and at university.

The longer-term effects of educational achievement were explored using a measure of gainful employment at age 29, 10 years after the end of upper secondary school. An individual was defined as gainfully employed if annual earnings corresponded to monthly earnings at least equal to the tenth centile of earnings in the Swedish population (earnings of SEK17,600 [11] or EUR1,903 in the calendar year when the individual turned 29 years). Earnings were deflated to the price level of 2007 using the consumer price index and the average exchange rate for 2007 (EUR1=SEK9.25 [12]). At this level of earnings, individuals would be able to support themselves on their income. Moreover, this level of earnings exceeded what a single adult with a child would receive as social allowance in the case of economic difficulty.

Analysis and statistical methods Unadjusted mean final grades were analysed using Student's t test, and we report the sex-adjusted OR of mortality. The impact of childhood onset of type 1 diabetes on educational attainment was analysed using logistic, linear, quantile and ordered logistic regression methods [13]. We used three main regression model specifications: model 1 estimated the effect of diabetes without controlling for potential confounders; model 2 controlled for sex, year when the grade was issued, and socioeconomic as well as Nordic vs non-Nordic background; and model 3 controlled for the same potential confounders as in model 2 but split the diabetes effect into groups defined by age of onset. The effect of diabetes on the mean final grade from upper secondary school was estimated separately for students graduating from theoretical programmes and students graduating from vocational programmes.

We estimated the OR of receiving a final grade from compulsory and upper secondary school, of graduating from a theoretical programme if graduating from upper secondary school, and of monthly earnings being ≥ EUR1,903 at the age of 29 years by logistic regression [13], controlling for confounders, according to model specifications 1–3 (excluding year when the grade was issued). In the analysis of monthly earnings at age 29, an additional model (model 4) included an interaction term of having diabetes and having graduated from upper secondary school to estimate potential accumulated effects of diabetes after age 19 (the age of completing upper secondary school).

To explore whether the impact of diabetes differed between groups of individuals, we used quantile regression [14] to estimate the effect of diabetes in the tenth, 25th, 50th, 75th and 90th quantiles of the conditional distribution of mean final grades. Ordered logistic regression, using a proportional odds model [15], was used to analyse the impact of diabetes on the grade in the three core subjects, Swedish, English and mathematics, and also in athletics.

Finally, to explore whether there was a trend in grades that could be associated with treatment development, we compared the grades of individuals diagnosed before with those of individuals diagnosed after 1984 (the median year of onset of diabetes in the study data).

Results

Figure 1 illustrates the study population at inclusion, at ages 16 and 19, and the number of people with final grades from compulsory and upper secondary school. At inclusion, girls

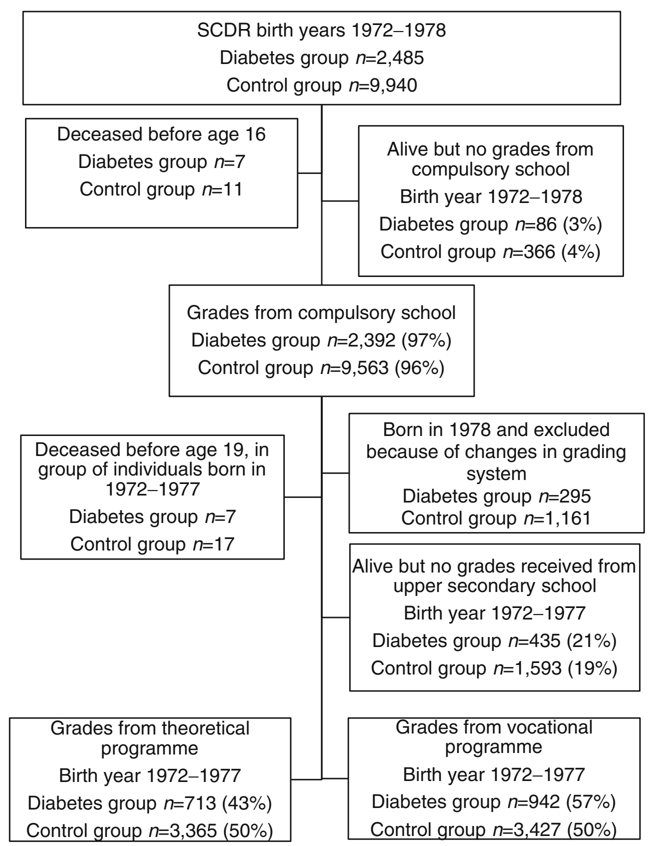

Fig. 1 Flow diagram showing inclusion and follow-up in the two groups included in the study: the diabetic group and the control group

were under-represented in the diabetes group (OR 0.86; 95% CI 0.79, 0.94). The mean (SD) age at diagnosis was 9.45 (3.50) years: 9.31 (3.34) years for girls and 9.57 (3.64) years for boys. Ten per cent were diagnosed at the age of 0–4 years, 38% at 5–9 years, and 53% at 10–15 years. The mean year of diagnosis was 1984, ranging from 1977 to 1993. Distributional graphs of age and year of diagnosis are available in electronic supplementary material (ESM) Figs 1 and 2.

Mortality was <1% in both groups, but sex-adjusted mortality at age 16 (OR 3.61; 95% CI 2.63, 4.95) and 19 (OR 4.45; 95% CI 3.09, 6.41) was higher in the diabetes group. We included 12,407 individuals born in 1972–1978 and alive at age 16 in the analysis of school grades from compulsory school and 10,475 individuals born during 1972–1977 and alive at age 19 in the analysis of grades from upper secondary school.

Mean final grades from compulsory school were available for the absolute majority of individuals: 97% of those with diabetes and 96% of controls (diabetes group vs controls; OR 0.82 [95% CI 0.62, 1.08], with confounders controlled for). Children with diabetes had lower unadjusted mean final grades (diabetes 3.13 [SD 0.75] vs controls 3.21 [SD 0.72], $p<0.001$), and children diagnosed at an early age, i.e. at 0–4 years, had a tendency towards a lower mean final grade from compulsory school, 3.06 (SD 0.71), although not significantly different at conventional levels.

A smaller proportion of individuals with diabetes completed upper secondary school (diabetics 79% vs controls 81%; OR 0.81 [95% CI 0.71, 0.92], with confounders controlled for). There were also differences in choice of study programme, and individuals with diabetes were less likely to have final grades from a theoretical programme (diabetes group 43% vs control group 50%; OR 0.78 [95% CI 0.69, 0.88], with confounders controlled for). Full regression results are available in ESM Table 1.

Among individuals receiving a grade from upper secondary school, the unadjusted mean final grade in the diabetes group was lower than in the control group (3.37 vs 3.43, $p=0.027$, for grades for programmes in preparation for higher education; 3.06 vs 3.11, $p=0.034$, for grades from the vocational programmes).

The results of linear regression analysis showed that the negative effect of diabetes on mean final grades from compulsory school also remained after demographic and socioeconomic characteristics were controlled for (compulsory school: model 1, −0.09, $p<0.001$; model 2, −0.07, $p<0.001$). The largest effect of diabetes, compared with the control group, was found among children diagnosed at the age of 0–4 years (compulsory school: model 3, −0.15, $p=0.001$) (Table 1).

In upper secondary school, the effect of diabetes was only statistically significant in the grades from programmes taken in preparation for higher education (model 2, −0.07, $p=0.001$ controlling for confounders). The largest effect was found among children younger than 10 years at the disease onset (−0.11, $p<0.001$, model 3). In the grades from vocational programmes, no statistically significant impact of diabetes was found when confounders were controlled for, not even among individuals with an early onset of the disease. Including mean grades from compulsory school as a variable in the regression models of upper secondary school grades considerably increased the coefficient of determination (R^2), e.g. from 0.05 to 0.46 in model 2 of grades from theoretical programmes. The effect of diabetes, however, changed only marginally. Full regression results are available in ESM Tables 2, 3 and 4.

In compulsory school, the greatest difference between the diabetes group and the control group was found in the grades in athletics (3.09 vs 3.31, $p<0.001$) (Table 2). Children with diabetes had a lower predicted probability of receiving top grades (grade 4: 0.25 vs 0.31, $p<0.001$; and grade 5: 0.06 vs 0.09, $p<0.001$) when demographic and socioeconomic variables were controlled for. The smallest difference between the two groups was seen in mathematics, where the small difference was still statistically significant owing to the large number of observations. Full regression results are shown in ESM Table 5.

Quantile regression showed differential effects of diabetes on the conditional distribution on mean final grades (Table 3). In compulsory school, the negative effect was strongest in the lowest decile (−0.13, $p<0.001$) and not significant in the top decile. In grades from programmes taken in preparation for higher education, the effect was statistically significant in the tenth, 25th and 50th quantile, with the largest negative effect also found in the tenth quantile (−0.12, $p=0.002$). In grades from vocational programmes, the negative effect was statistically significant in the 50th quantile (−0.05, $p<0.001$).

We found no indication of differences in unadjusted mean final grades in the diabetes group relating to year of diagnosis (before/after 1984): 3.11 vs 3.14 ($p=0.283$) in compulsory school, and 3.35 vs 3.39 ($p=0.356$) and 3.06 vs 3.07 ($p=0.869$) in theoretical and vocational programmes in upper secondary school, respectively.

Table 4 shows that individuals with type 1 diabetes were less likely to be gainfully employed at 29 years old in the unadjusted model (model 1) and when confounders were controlled for (model 2). Model 4 showed that individuals with diabetes who did not have upper secondary school education were considerably worse off in the labour market at the age of 29 years compared with controls without upper secondary education (OR 0.66; 95% CI 0.51, 0.87). Finishing upper secondary school on average about doubled the chances of being gainfully employed at the age of 29 (diabetes group, OR 1.92 [95% CI 1.63, 2.62]; controls, OR

Table 1 Linear regression of the effect of diabetes on the mean final grades from compulsory and upper secondary school

Diabetes effect	β±SE	95% CI	*p* value
Compulsory school			
Model 1: unadjusted effect of diabetes (*n*=11,955)	−0.09±0.02	−0.12, −0.54	<0.001
Model 2: effect of diabetes after controlling for confounders[a] (*n*=11,236)	−0.07±0.02	−0.10, −0.04	<0.001
Model 3: effect of age at diagnosis of diabetes after controlling for confounders[a] (*n*=11,236)			
Controls (reference group)			
Onset of diabetes at 0–4 years	−0.15±0.05	−0.24, −0.06	0.001
Onset of diabetes at 5–9 years	−0.07±0.02	−0.12, −0.03	0.001
Onset of diabetes at 10–15 years	−0.06±0.02	−0.10, −0.02	0.003
Upper secondary school—theoretical programmes			
Model 1: unadjusted effect of diabetes (*n*=4,078)	−0.06±0.03	−0.11, −0.01	0.029
Model 2: effect of diabetes after controlling for confounders[b] (*n*=3,840)	−0.07±0.02	−0.11, −0.03	0.001
Model 3: effect of age at diagnosis of diabetes after controlling for confounders[b] (*n*=3,840)			
Controls (reference group)			
Onset of diabetes at 0–4 years	−0.11±0.05	−0.20, −0.01	0.025
Onset of diabetes at 5–9 years	−0.11±0.03	−0.17, −0.05	<0.001
Onset of diabetes at 10–15 years	−0.03±0.03	−0.08, 0.02	0.236
Upper secondary school—vocational programme			
Model 1: unadjusted effect of diabetes (*n*=4,369)	−0.05±0.02	−0.09, −0.00	0.031
Model 2: effect of diabetes after controlling for confounders[b] (*n*=4,098)	−0.02±0.02	−0.06, 0.01	0.181
Model 3: effect of age at diagnosis of diabetes after controlling for confounders[b] (*n*=4,098)			
Controls (reference group)			
Onset of diabetes at 0–4 years	−0.03±0.06	−0.14, 0.08	0.644
Onset of diabetes at 5–9 years	0.01±0.02	−0.04, 0.05	0.833
Onset of diabetes at 10–15 years	−0.04±0.02	−0.09, 0.00	0.066

[a] Controlling for sex, year of grade, socioeconomic background and country of birth (Nordic/non-Nordic) of the parents

[b] Controlling for sex, year of grade, socioeconomic background, country of birth (Nordic/non-Nordic) of the parents and mean final grade from compulsory school

Table 2 Predicted probability of receiving final grades 1–5 in English, Swedish, mathematics and athletics in compulsory school

Subject	Mean grade[a]	Grade[b]				
		1	2	3	4	5
English						
Diabetes group	3.14	0.024	0.195	0.440	0.281	0.061
Controls	3.23	0.020	0.174	0.429	0.305	0.071
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Swedish						
Diabetes group	3.10	0.024	0.213	0.425	0.278	0.060
Controls	3.15	0.021	0.196	0.418	0.297	0.068
p value	0.024	<0.001	<0.001	<0.001	<0.001	<0.001
Mathematics						
Diabetes group	3.13	0.029	0.209	0.406	0.283	0.069
Controls	3.15	0.028	0.213	0.404	0.288	0.072
p value	0.278	0.004	0.002	0.001	0.001	0.002
Athletics						
Diabetes group	3.09	0.047	0.161	0.483	0.248	0.061
Controls	3.31	0.031	0.117	0.450	0.312	0.090
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[a]Unadjusted mean grades

[b]Predicted probability controlling for sex, year of grade, socioeconomic background and country of birth of the parents (Nordic/non-Nordic)

Table 3 Quantile regression of the diabetes effect on the mean final grade from compulsory and upper secondary school

Quantile	Compulsory school[a]		Upper secondary school[b]			
			Theoretical programmes		Vocational programmes	
	β±SE	*p* value	β±SE	*p* value	β±SE	*p* value
10th	−0.13±0.04	<0.001	−0.12±0.04	0.002	−0.02±0.03	0.564
25th	−0.10±0.02	<0.001	−0.08±0.02	0.001	−0.03±0.02	0.161
50th	−0.07±0.02	<0.001	−0.07±0.03	0.009	−0.05±0.01	<0.001
75th	−0.06±0.02	<0.001	−0.05±0.03	0.128	−0.03±0.02	0.091
90th	−0.01±0.03	0.790	−0.05±0.04	0.169	0.01±0.03	0.642

[a] Controlling for sex, year of grade, socioeconomic background and country of birth of the parents (Nordic/non-Nordic)

[b] Controlling for sex, year of grade, socioeconomic background, country of birth of the parents (Nordic/non-Nordic) and mean final grade from compulsory school

2.21 [95% CI 1.93, 2.53]; Table 4). Full regression results are shown in ESM Table 6.

Discussion

Childhood onset of type 1 diabetes negatively affects educational achievement in compulsory school and in upper secondary school in programmes taken in preparation for higher education, also after adjustment for socioeconomic background, sex and country of origin. The effect was small but statistically significant. Moreover, in this cohort born in 1972–1977, the results indicated accumulated negative effects of type 1 diabetes, measured as a lower probability of gainful employment at 29 years of age. Among children with diabetes, there was a tendency of greater negative impact among those who were diagnosed early in childhood (0–4 years old) (Table 1) and among those with lower grades, although confidence intervals overlapped (Table 3). The effect of age at diabetes onset is consistent with direct effects, such as hypo- and hyper-glycaemic episodes, which are more dangerous for the brain in early childhood [16, 17]. Furthermore, these children have also lived longer with the disease. The difference in the effect of diabetes across the grade distribution suggests that diabetes may be a greater challenge for children with weaker overall school performance.

The effect of diabetes in upper secondary school was estimated, controlling for the mean final grade from

Table 4 OR of being gainfully employed 10 years after upper secondary school in individuals born during 1972–1977

OR of employment (earnings ≥ EUR1,903/month)	OR	95% CI
Model 1: unadjusted effect of diabetes (*n*=10,041)	0.89	0.80, 0.98
Model 2: effect of diabetes, controlling for confounders[a] (*n*=9,392)	0.82	0.73, 0.91
Model 3: effect age at diagnosis of diabetes, controlling for confounders[a] (*n*=9,392)		
Controls (reference group)		
Onset of diabetes at 0–4 years	0.87	0.62, 1.23
Onset of diabetes at 5–9 years	0.77	0.65, 0.90
Onset of diabetes at 10–15 years	0.85	0.73, 0.97
Model 4: controlling for confounders[b] (*n*=9,392)		
Control/no upper secondary education (reference)		
Control/upper secondary education	2.21	1.93, 2.53
Diabetes/no upper secondary education	0.66	0.51, 0.87
Diabetes/upper secondary education[c]	1.92	1.63, 2.62

[a] Controlling for sex, socioeconomic background and country of birth of the parents (Nordic/non-Nordic)

[b] Controlling for sex, socioeconomic background, country of birth of the parents (Nordic/non-Nordic) and completing upper secondary education

[c] The combined OR for ‘Diabetes/upper secondary education’ was extracted as the linear combinations of estimators ‘Diabetes’, ‘Upper secondary education’ and ‘Diabetes/upper secondary education’ (see ESM Table 6)

compulsory school. Thus the estimated diabetes effect was the impact of diabetes on top of effects already manifested in compulsory school. However, when controlling for confounders, we found no significant effect of diabetes among individuals attending a vocational programme, an indication that theoretical programmes may be perceived as more time-demanding and harder to combine with having diabetes.

A major strength of this study was that it was population-based and involved prospectively recorded, individual-level national register data on over 12,000 individuals, 2,485 of whom had been diagnosed with diabetes during 1977–1993. Moreover, we were able to analyse mean final grades at graduation from compulsory school (age 16) and upper secondary school (age 19), as well as the probability of gainful employment 10 years after leaving school (age 29). The negative effect of diabetes was robust across all analyses and regression methods, with different sets of confounders used (models 1–4).

A potential weakness of the study was that unobserved genetic or environmental factors that correlate with both the onset of diabetes type 1 and schooling may have biased our estimate of the impact of diabetes. It is well recognised that type 1 diabetes is caused by a complex combination of genetic and environmental factors [18]. The onset is often sudden and unanticipated. We assumed that the onset and its direct negative effects on the child's health could not be influenced or anticipated in advance by the child or his or her family. Accordingly, we expected the systematic differences in socioeconomic and background characteristics between the diabetes group and controls to be small, if present at all. This was a reasonable assumption since heredity plays a minor role in type 1 diabetes [19]. Earlier results from the SCDR showed that 91.5% of the children had no parent with insulin-dependent diabetes, compared with 98.9% among the reference group [20]. In this study sample, boys and children with parents born in a Nordic country had a higher risk of diabetes (ESM Table 7), in accordance with previous studies on the incidence of type 1 diabetes [21, 22]. In the regression analyses, we adjusted for these variables. However, there was no evidence that socioeconomic background was associated with the onset of diabetes, although the links between parents' and their children's level of education are well established and have been shown again in this study. Nevertheless, we cannot rule out the possibility that there may be other, unobserved factors that correlated with both the onset of type 1 diabetes and schooling, but it is unlikely that results would be radically different.

A limitation of using national individual-level statistics was that the data did not permit us to separate psychosocial effects from possible biological effects due to early onset of diabetes. Furthermore, the available registry data did not include enough information to analyse the influence of family structure in this study. If divorces impact on diabetes treatment adherence, this may also affect school achievements. We have analysed final school grades for people with diabetes and controls, but we have not decomposed the underlying mechanisms and pathways.

We found, in line with the so far limited evidence [1–5, 23], that the onset of diabetes has a small negative effect on school achievements. In this study, we also quantified the negative impact in absolute terms as difference in mean final grades, while earlier studies mainly reported differences in educational outcome in relative terms using ORs. Furthermore, earlier studies typically relied on small cross-sectional datasets and moreover did not account for the impact of socioeconomic background [1].

The association between diabetes and educational achievement can be explained by several factors. According to the human capital theoretical framework, differences could be explained by reduced incentives to invest in education because of increased uncertainty about future productivity and life expectancy [24]. This interpretation may apply in particular when interpreting the results for upper secondary school, where individuals are closer to adult life and may be thinking of education as investing in the future. At both school stages, the time demands of handling the disease compete with study time. Early severe hypoglycaemia [17], as well as attention and memory difficulties due to minor episodes of hypoglycaemia [3], may also have short- and long-term effects on grades at both educational levels studied. Earlier studies have indicated increased absenteeism from school in children with diabetes, which can be expected to negatively affect educational achievement [1, 2].

Finally, the question needs to be answered whether the small negative effect of diabetes in compulsory and upper secondary school grades is large enough to matter in a broader sense? On the assumption that higher education leads to benefits on the labour market in the form of more attractive and higher paid jobs, we believe that slightly lower grades and lower probability of completing a programme preparing for higher education may result in a disadvantage that can follow individuals with diabetes through life. Even though the mean negative effect is small, it could still mean the qualitative difference between being admitted or not to a programme of choice in upper secondary school and at university. The long-term effect may be fewer career opportunities and a lower salary. In this study, the lower likelihood of gainful employment at age 29 was an early indication of persisting difference. The fact that the impact of diabetes on the likelihood of employment remained after we controlled for differences in education can be seen as an indication of productivity reduction and perhaps also discrimination in the labour market due to the disease.

This study investigates the impact of type 1 diabetes on the first 12 years of formal education. The long-term socioeconomic effect of diabetes, however, needs to be further investigated. Further research is needed to explore the consequences of diabetes beyond upper secondary education where the impact may differ over time and between different social systems and countries.

One hypothesis is that the negative effect of diabetes will diminish over time because of improved tools for self-management, more patient education, and intensified treatment regimens following the DCCT [25]. Our cohort was born during 1972–1978 and experienced the onset of type 1 diabetes in 1977–1993, which means that they have seen the introduction of new treatment technologies. For example, the measurement of HbA_{1c} and self-monitoring of blood glucose became standard in the 1980s, and multiple injection regimens were introduced in Sweden around 1985 and spread rapidly as it was strongly recommended by the Swedish Paediatric Association Working Group on Childhood Diabetes. We hypothesised that year of onset could be associated with educational achievement if onset in the late 1970s to early 1980s meant lower implementation of these new treatment technologies. However, we did not find any significant differences within our cohort. This does not preclude that later cohorts may close the gap in educational outcome compared with controls.

In conclusion, the results from this study indicate that an onset of type 1 diabetes in childhood negatively affects educational achievements, in both compulsory schooling and theoretical programmes in upper secondary school, and that it potentially also affects future participation in the labour market. There was a tendency that children with an early onset of diabetes and children with lower school grades were most affected. These findings support collaborations between families, clinicians and teachers to identify and assist especially vulnerable children and teenagers.

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