Published in final edited form as:

Diabet Med. 2016 May ; 33(5): 668–673. doi:10.1111/dme.12854.

Research: Educational/Psychological Aspects Academic abilities and glycaemic control in children and young people with Type 1 diabetes mellitus

K. Semenkovich¹, P. P. Patel¹, A. B. Pollock², K. A. Beach¹, S. Nelson⁶, J. J. Masterson⁷, T. Hershey^{3,4,5}, and A. M. Arbeláez¹

¹Department of Pediatrics, Washington University School of Medicine, St. Louis

²Department of Occupational Therapy, Washington University School of Medicine, St. Louis

³Department of Psychiatry, Washington University School of Medicine, St. Louis

⁴Department of Neurology, Washington University School of Medicine, St. Louis

⁵Department of Radiology, Washington University School of Medicine, St. Louis

⁶Department of Biostatistics, Washington University School of Medicine, St. Louis

⁷Department of Communication Sciences and Disorders, Missouri State University, Springfield, MO, USA

Abstract

Aims—To determine if children and young people aged < 23 years with Type 1 diabetes differ in academic ability from age-matched control subjects without Type 1 diabetes and whether academic scores are related to glycaemic control.

Methods—Using a cross-sectional study design, we administered cognitive and academic tests (Woodcock-Johnson III Spatial Relations, General Information, Letter-Word Recognition, Calculation and Spelling tests) to young people with Type 1 diabetes ($n=61$) and control subjects ($n=26$) aged 9–22 years. The groups did not differ in age or gender. Participants with Type 1 diabetes had a disease duration of 5–17.7 years. History of glycaemic control (HbA_{1c}, diabetic ketoacidosis and severe hypoglycaemic episodes) was obtained via medical records and interviews.

Results—The participants with Type 1 diabetes had a lower mean estimated verbal intelligence (IQ) level compared with those in the control group ($P=0.04$). Greater exposure to hyperglycaemia over time was associated with lower spelling abilities within the group with Type 1 diabetes ($P=0.048$), even after controlling for age, gender, socio-economic status, blood glucose level at time of testing and verbal IQ ($P=0.01$). History of severe hypoglycaemia or ketoacidosis was not associated with differences in academic abilities.

Correspondence to: Ana Maria Arbeláez. Arbelaez_A@kids.wustl.edu.

Competing interests

None declared.

Conclusions—In children and young people, Type 1 diabetes was associated with a lower verbal IQ. Moreover, increased exposure to hyperglycaemia was associated with lower spelling performance. These results imply that hyperglycaemia can affect cognitive function and/or learning processes that may affect academic achievement.

Introduction

Children with Type 1 diabetes perform less well in a range of cognitive domains compared with control groups, which some studies have linked to their history of glycaemic control [1–3]; however, the impact that these cognitive differences have on academic achievement is unclear. Even though some studies have found no difference in academic abilities between children with Type 1 diabetes and control subjects, others have reported lower academic performance in children with Type 1 diabetes [4–6]; however, the clinical factors inherent in Type 1 diabetes responsible for these conflicting results remain unclear. There is limited information on the relationship between degree of glycaemic exposure and academic abilities in children and young people with Type 1 diabetes [5,7–9]; therefore, the aim of the present study was to determine whether children and young people with Type 1 diabetes differ from control subjects without Type 1 diabetes on standardized academic skills tests, after controlling for verbal IQ using the Woodcock-Johnson III (WJIII) General Information test and blood glucose levels at the time of testing. An additional aim of this study was to determine if degree of exposure to hyperglycaemia relates to academic abilities within Type 1 diabetes. We hypothesized that Type 1 diabetes and greater exposure to hyperglycaemia would be related to decreased academic and cognitive performance in children and young people with Type 1 diabetes compared with control subjects.

Participants and methods

Participants

We conducted a cross-sectional analysis of 87 children and young people (age 9–22 years, 61 subjects with Type 1 diabetes, 26 control subjects without Type 1 diabetes). These people were part of a longitudinal study (the primary outcomes have been published previously [10]). Participants with Type 1 diabetes were recruited from the Washington University Paediatric Diabetes Clinic between 2003 and 2010. Those with Type 1 diabetes met the diagnostic criteria of the American Diabetes Association's (ADA) [11] and had been diagnosed for at least 2 years. In addition they had to have been on a basal-bolus insulin regimen, with at least four daily insulin injections, or an external pump. Subjects from both groups were excluded if their native language was not English, or if they had been diagnosed with another medical condition (i.e. learning disability, attention deficit disorder, temporal lobe epilepsy, Crohn's disease, previous head injury, drug or alcohol abuse, psychiatric disorders), known premature birth (< 26 weeks' gestation), or if they were taking any psychoactive medications. All participants and their parents provided written informed consent and assent approved by the Washington University Human Research Protection Office.

Procedures

All participants underwent assessments examining cognitive and academic abilities that lasted ~3 h. Testing of participants with Type 1 diabetes was conducted when their blood glucose level was between 4 mmol/l (70 mg/dl) and 17 mmol/l (300 mg/dl). The medical and glycaemic history of participants with Type 1 diabetes were obtained from their medical records and from interviews. Patient and parental interviews and medical chart reviews were used to assess history of severe hypoglycaemia and diabetic ketoacidosis.

Cognitive and academic measures

To estimate intelligence, a verbal IQ test (WJIII General Information test) and a spatial IQ test (Spatial Relations test) [12] were administered to all participants. Academic abilities were assessed using the WJIII Letter-Word Recognition, Calculation and Spelling academic tests. These individual tests have reliabilities between 0.80 and 0.90. Scaled scores and percentiles were obtained by comparing raw scores to age and gender norms.

For a more detailed assessment of spelling errors made in the WJIII subtest the Spelling Sensitivity System was applied [13]. This scoring system characterizes errors based on the degree of linguistic knowledge they represent. A spelling sensitivity score was obtained by dividing the number of points awarded to each word by the total number of words in the sample. Each target word is scored on a scale of 0 to 3. A score of < 1 indicates that there were omissions in the spellings (e.g. 'grage' for 'garage') and represents the lowest level of linguistic knowledge. A score between 1 and 2 typically suggests that a child's spelling is phonologically accurate; however, the orthographic conventions are still deficient (i.e. used 'illegal' or implausible, spelling conventions, as in 'cosx' for 'coax'). A score > 2 suggests that the child used 'legal' (plausible) spellings and has adequate orthographic skills, however, the child may need to work on fine-tuning mental graphic representations (e.g. 'vasolate' for 'vacillate'). A spelling score of 2 indicates greater linguistic knowledge because of the accuracy of the phonological and orthographic elements, despite not being entirely accurate. A score of 3 indicates that the spelling for the target word was accurate.

Degree of glycaemic control

Three aspects of glycaemic control from diagnosis to time of testing were assessed: 1) degree of exposure to hyperglycaemia over time; 2) number of severe hypoglycaemic episodes; and 3) number of diabetic ketoacidosis episodes. As the degree of exposure to hyperglycaemia over time best predicts diabetic microvascular complications, we explored the relationship of this variable independently of ketoacidosis and severe hypoglycaemia. In diabetes, the degree of exposure to hyperglycaemia is dependent on the duration of the disease and the level of hyperglycaemia (measured via HbA_{1c} concentration); therefore, we estimated a hyperglycaemia exposure score for each patient, in which the median lifetime HbA_{1c} is weighted by duration of diabetes. This hyperglycaemia exposure score was calculated for each patient in the following manner. First, disease duration and median lifetime HbA_{1c} variables were transformed into standard z-scores for the entire sample. Second, for each patient, we added the patient's disease duration z-score to that patient's median lifetime HbA_{1c} z-score [14]. This summed z-score therefore equally reflects disease duration and degree of glucose control, allowing us to differentiate between two subjects

with a similar median lifetime HbA_{1c} (e.g. 8.5%) but a different disease duration (e.g. 2 vs. 10 years). The latter participant would have a much higher summed z-score (hyperglycaemia exposure score) than the former, capturing the different degree of exposure to hyperglycaemia of these two participants.

The number of severe hypoglycaemic and ketoacidosis episodes was obtained through a detailed interview and medical chart review. Severe hypoglycaemic events were defined using the Diabetes Control and Complications Trial (DCCT) criteria and the ADA criteria [15]. The DCCT defines a severe hypoglycaemic episode as an event with neurological dysfunction including seizure, loss of consciousness or inability to arouse. As per the ADA criteria, a hypoglycaemic event was also considered severe if hypoglycaemic symptoms were so severe that the participants were unable to treat themselves. Ketoacidosis was defined using the DCCT criteria of a bicarbonate concentration < 15 mmol/l. The number of severe hypoglycaemic and diabetic ketoacidosis episodes was broken down into two categories (no past severe episodes, and one or more episodes).

Statistical analyses

We used SPSS (IBM Statistics for Macintosh, version 22.0, IBM Corp., Armonk, NY, USA) to analyse the results. We compared demographic and glycaemic control variables between people with Type 1 diabetes and control subjects using *t*-tests and chi-squared tests. We used univariate general linear models to determine group differences on cognitive and academic abilities. For effect sizes we used Cohen's *d* for univariate general linear models and a β coefficient for linear regressions. We reported the R^2 change for estimates of variance. We analysed the association between glycaemic control variables and cognitive and academic abilities within the group with Type 1 diabetes using general linear models and hierarchical linear regressions. For all general linear models and hierarchical linear regressions, age, gender and socio-economic status were covaried. Additional specific analyses also covaried other variables (e.g. verbal IQ, blood glucose levels at the time of testing). Socio-economic status scores were calculated according to Barratt, an updated version of the Hollingshead Four Factor Index [16,17]. Two tailed *P* values of < 0.05 were taken to indicate statistical significance.

Results

Demographics and glycaemic control

There was no difference between participants with Type 1 diabetes and control subjects in age [$t=1.40$, $P=0.16$, gender chi-squared (1, $n=87$)= 0.01 ; $P=0.91$] or socio-economic status [$t=-0.62$; $P=0.54$ (Table 1)].

Of the 61 participants with Type 1 diabetes, 35 had no previous severe hypoglycaemic episodes, and 26 had a history of at least one severe hypoglycaemic episode. There were 44 participants with Type 1 diabetes with no previous ketoacidosis events, and 17 with at least one episode of ketoacidosis (Table 1).

Associations with cognitive and academic abilities

Between-group comparisons showed that on average, the group of participants with Type 1 diabetes performed less well than those in the control group (Table 1) on the verbal IQ test: $F(4, 82)=4.59$, $P=0.04$, $d=0.47$, but not on the spatial IQ test: $F(4, 82)=1.18$, $P=0.28$, $d=0.24$. Groups did not differ on tests of academic ability: Letter-Word Identification: $F(4, 82)=1.18$, $P=0.28$, $d=0.24$; Calculation: $F(4, 82)=0.01$, $P=0.94$, $d=0.0$; Spelling: $F(4, 82)=1.80$, $P=0.18$, $d=0.29$.

Analyses within the group with Type 1 diabetes showed that: age of onset of Type 1 diabetes was not associated with IQ or tests of academic ability: Verbal IQ: $F(3, 56)=2.31$, $P=0.13$, $\beta=-.25$, R^2 change=0.13; Spatial IQ: $F(3, 56)=2.58$, $P=0.85$, $\beta=0.030$, R^2 change=0.12; Letter-Word Identification: $F(3, 56)=0.36$, $P=0.98$, $\beta=-0.01$, R^2 change=0.02; Calculation: $F(3, 56)=3.32$, $P=0.08$, $\beta=-0.28$, R^2 change=0.19; and Spelling: $F(3, 56)=0.81$, $P=0.26$, $\beta=0.19$, R^2 change=0.04. We did not covary for age of onset therefore in subsequent analyses of glycaemic variables.

The results also showed that IQ and academic skills did not differ across severe hypoglycaemic episode categories: Verbal IQ: $F(4, 56)=0.74$, $P=0.39$, $d=0.23$; Spatial IQ: $F(4, 56)=4.06$, $P=0.05$, $d=0.54$; Letter-Word Identification: $F(4, 56)=0.01$, $P=0.95$, $d=0.0$; Calculations: $F(4, 56)=1.05$, $P=0.31$, $d=0.27$; Spelling: $F(4, 56)=3.21$, $P=0.08$, $d=0.48$.

Academic skills and IQ did not differ across diabetic ketoacidosis episode categories: Verbal IQ: $F(4, 56)=0.94$, $P=0.34$, $d=0.26$; Spatial IQ: $F(4, 56)=1.17$, $P=0.28$, $d=0.29$; Letter-Word Identification: $F(4, 56)=1.38$, $P=0.25$, $d=0.31$; Calculations: $F(4, 56)=0.07$, $P=0.79$, $d=0.06$; Spelling: $F(4, 56)=0.01$, $P=0.91$, $d=0.0$.

Degree of exposure to hyperglycaemia (sum of: z scores for duration of diabetes and median lifetime HbA_{1c}) was not associated with IQ, reading or mathematics scores: Verbal IQ: $F(3, 49)=0.99$, $P=0.57$, $\beta=0.09$, R^2 change=0.07; Spatial IQ: $F(3, 49)=2.65$, $P=0.86$, $\beta=0.03$, R^2 change=0.17; Letter-Word Identification: $F(3, 49)=0.26$, $P=0.73$, $\beta=-0.06$, R^2 change=0.01; Calculation: $F(3, 49)=2.65$, $P=0.77$, $\beta=-0.04$, R^2 change=0.18. Hyperglycaemia exposure did relate to Spelling ability: $F(3, 49)=1.496$, $P=0.048$, $\beta=-0.32$, R^2 change=0.04. After controlling for verbal IQ and blood glucose levels at the time of testing (Fig. 1), the relationship between hyperglycaemia exposure and Spelling ability became stronger: $F(5, 47)=4.08$, $P=0.01$, $\beta=-0.36$, R^2 change=0.28.

To further understand the effects we observed in overall spelling, we examined the spelling sensitivity score. On this more specific score, the group with Type 1 diabetes scored lower than controls: $F(4, 82)=4.29$, $P=0.04$, $d=0.46$ (Table 1); however, within the group with Type 1 diabetes, hyperglycaemia exposure did not correlate with this score: $F(3, 49)=4.97$, $P=0.34$, $\beta=-0.14$, R^2 change=0.28 (Table 1).

An additional analysis excluding the nine sibling control subjects found no effect of group on Verbal IQ: $F(4, 73)=3.63$, $P=0.061$, $d=0.44$, or on the spelling sensitivity score: $F(4, 73)=1.84$, $P=0.18$, $d=0.32$; however, the effect of hyperglycaemia exposure on spelling ability did not change: $F(3, 49)=1.496$, $P=0.048$, $\beta=-0.32$, even after controlling for Verbal

IQ and blood glucose levels: $F(5, 47)=3.95$, $P=0.01$, $\beta=-0.36$. Notably, effect sizes for all of these analyses were very similar to analyses with the entire sample, suggesting that any differences in P values were driven by the reduced sample size, not by sibling status.

Discussion

The present study shows that children and young people with Type 1 diabetes had a lower verbal IQ and a greater tendency to spell words in a less linguistically sophisticated manner compared with control subjects. Moreover, we found that the participants with Type 1 diabetes with more previous exposure to hyperglycaemia had lower overall spelling abilities compared with those with less hyperglycaemia exposure. The present study adds specificity and improved experimental control to the limited literature on the academic impact of Type 1 diabetes in children and young people.

Previous work on the link between Type 1 diabetes and academic skills has used a variety of methods. One recent study used teacher reports, not direct assessment, to estimate students' skills and difficulties and a most recent HbA_{1c} level to estimate hyperglycaemia exposure [8]. They found that children with Type 1 diabetes with higher most recent HbA_{1c} levels had more teacher-rated inattention and lower academic performance. A re-analysis of older data from two small studies [9] indicated that people with a longer duration of Type 1 diabetes and higher HbA_{1c} levels may be at a higher risk of learning disabilities. Notably, unlike the present study, these studies did not exclude subjects with learning disabilities or attention deficit disorders or control for blood glucose levels at the time of assessments; thus, the implications of this work for our findings are probably limited.

Using methods similar to those used in the present study, a previous study found that subjects with early onset Type 1 diabetes had lower performance in spelling and reading compared with control subjects, particularly in those who had a higher HbA_{1c} a year after diagnosis [7,9]. These similar findings, although in a more restricted sample of children with early-onset Type 1 diabetes, support the overall pattern of our findings; thus, spelling performance may be a particularly sensitive measure of cognition in children with Type 1 diabetes. Some studies have found that brain regions associated with language and spelling processing, such as the cuneus and precuneus, are altered in people with spelling deficits [18–20]. Interestingly, decreased volume in the precuneus and cuneus has been noted in young people and adults with Type 1 diabetes and may correlate with hyperglycaemia exposure [21,22]. It is possible that selective effects of hyperglycaemia on these spelling-related cortical regions could explain the selective spelling issues in young people with Type 1 diabetes, but direct evidence of this relationship is lacking.

Similarly to previous research [4,5], children and young people with Type 1 diabetes performed less well than control subjects without Type 1 diabetes on a verbal IQ measure; however, verbal IQ scores did not explain our spelling ability findings. The verbal IQ finding did not seem to be driven by previous exposure to such severe glycaemic extremes as severe hypoglycaemia or severe hyperglycaemia, including HbA_{1c} at diagnosis. Unlike previous studies, we did not find an effect of age of onset of diabetes on cognitive outcomes [3,23].

The lack of this association may be attributable to the nature of our sample, which included relatively few patients diagnosed before the age of 5 years ($n=17$).

The calculation and reading skills, in contrast to the lower spelling scores in children and young people with Type 1 diabetes, were not different from those in control subjects. Moreover, the mean performance of all groups and subgroups on all three academic tests and IQ tests fell within the average range, suggesting that the relatively subtle differences that we observed are occurring within a functional range of performance, without necessarily indicating the presence of any significant clinical or academic deficit at the group level. Given that we excluded anyone with a clinical diagnosis of a learning disability or attention deficit disorder, this overall high level of function may be an overestimation of the variability in the general population of children and young people with Type 1 diabetes and control subjects.

The present study is novel as it examined children and young people with Type 1 diabetes with a wider range of age of onset and disease duration, making our findings more generalizable to the school-aged population of children with Type 1 diabetes. Additionally, we assessed the impact of hyperglycaemia exposure from diagnosis to time of testing, taking into account duration of exposure, which no other academic skills study has done. We attempted to control for all possible variables that could influence our results in our hierarchical model, but we acknowledge that the present study has some limitations. It had modest sample sizes for both groups. In addition, analyses of the effects of severe hypoglycaemia and ketoacidosis were limited because of the low frequency of these events in this sample. Also, we did not have data on school attendance, but, according to one study in children with Type 1 diabetes, having a greater number of missed school days did not have a significant effect on general academic performance [5].

Longitudinal studies are needed to further understand the impact that Type 1 diabetes *per se*, as well as glycaemic extremes or degree of hyperglycaemia exposure, may have on brain structure and function and their consequences for everyday life. Such studies would allow us to better understand the mechanisms involved in the cognitive differences found in this and other studies, and may enable us to identify risk factors, which could lead to better clinical practice. For example, evaluating spelling skills based on the types of errors occurring may result in earlier identification of potential academic risks, which could lead to beneficial instructional intervention. Currently, it is not part of routine clinical care to assess potential academic or cognitive deficits in patients with Type 1 diabetes. In addition, the current recommended HbA_{1c} target is higher in younger patients with Type 1 diabetes compared with older children [24] and the ADA reports that many school environments do not have the necessary accommodations to maintain even these recommendations throughout the school day [25]. In contrast, our findings and others suggest that achieving tighter glycaemic control early in childhood may be important for minimizing risk for suboptimum cognitive and academic development.

Acknowledgments

Funding sources

This work was supported by the National Institutes of Health under Grants (DK64832 and ULRR24992), the Washington University General Clinical Research Center under Grant (RR00036), the Clinical and Translational Science Award Grant (UL1 TR000448), the Siteman Comprehensive Cancer Center and National Cancer Institute Cancer Center Support Grant (P30 CA091842) and funds from the Dana Foundation, and the Harold Amos Medical Faculty Development Program.

We thank the SLCH Pediatric Clinical Research Unit staff for their assistance with the patients during the study.

References

- Desrocher M, Rovet J. Neurocognitive correlates of type 1 diabetes mellitus in childhood. *Child Neuropsychol.* 2004; 10:36–52. [PubMed: 14977514]
- Hershey T, Perantie D, Warren S, Zimmerman E, Sadler M, White N. Frequency and timing of severe hypoglycemia affects spatial memory in children with type 1 diabetes. *Diabetes Care.* 2005; 28:2372–2377. [PubMed: 16186265]
- Lin A, Northam E, Rankins D, Werther G, Cameron F. Neuropsychological profiles of young people with type 1 diabetes 12 yr after disease onset. *Pediatr Diabetes.* 2010; 11:235–243. [PubMed: 20070555]
- Dahlquist G, Kallen B. Swedish Childhood Diabetes Study Group. School performance in children with type 1 diabetes—a population-based register study. *Diabetologia.* 2007; 50:957–964. [PubMed: 17333107]
- McCarthy A, Lindgren S, Mengeling M, Tsalikian E, Engvall J. Factors associated with academic achievement in children with type 1 diabetes. *Diabetes Care.* 2003; 26:112–117. [PubMed: 12502666]
- Wodrich DL, Hasan K, Parent KB. Type 1 diabetes mellitus and school: a review. *Pediatr Diabetes.* 2011; 12:63–70. [PubMed: 20546162]
- Hannonen R, Komulainen J, Riikonen R, Ahonen T, Eklund K, Tolvanen A, et al. Academic skills in children with early-onset type 1 diabetes: the effects of diabetes-related risk factors. *Dev Med Child Neurol.* 2012; 54:457–463. [PubMed: 22590723]
- Parent K, Wodrich D, Hasan K. Type 1 diabetes mellitus and school: a comparison of patients and healthy siblings. *Pediatr Diabetes.* 2009; 10:554–562. [PubMed: 19496963]
- Rovet J, Ehrlich R, Czuchta D, Akler M. Psychoeducational characteristics of children and adolescents with insulin-dependent diabetes mellitus. *J Learn Disabil.* 1993; 26:7–22. [PubMed: 8418193]
- Perantie D, Koller J, Weaver P, Lugar H, Black K, White N, et al. Prospectively determined impact of type 1 diabetes on brain volume during development. *Diabetes.* 2011; 60:3006–3014. [PubMed: 21953611]
- Standards of medical care in diabetes—2013. *Diabetes Care.* 2013; 36 (Suppl 1):S11–66. [PubMed: 23264422]
- Woodcock, R.; McGrew, K.; Mather, N. Woodcock-Johnson III General Information and Spatial Relations Tests. Itasca: Riverside Publishing; 2001.
- Julie M, Kenn A. The spelling sensitivity score: noting developmental changes in spelling knowledge. *Assess Eff Interv.* 2010; 36:35–45.
- Perantie D, Wu J, Koller J, Lim A, Warren S, Black K, et al. Regional brain volume differences associated with hyperglycemia and severe hypoglycemia in youth with type 1 diabetes. *Diabetes Care.* 2007; 30:2331–2337. [PubMed: 17575089]
- The DCCT Research Group. Epidemiology of severe hypoglycemia in the diabetes control and complications trial. *Am J Med.* 1991; 90:450–459. [PubMed: 2012085]
- Barratt, W. Barratt Simplified Measure of Social Status (BSMSS). Terre Haute, IN: Indiana State University; 2006.
- Hollingshead AB. Four factor index of social status. 1975
- Gebauer D, Enzinger C, Kronbichler M, Schurz M, Reishofer G, Koschutnig K, et al. Distinct patterns of brain function in children with isolated spelling impairment: new insights. *Neuropsychologia.* 2012; 50:1353–1361. [PubMed: 22401987]

19. Gebauer D, Fink A, Kargl R, Reishofer G, Koschutnig K, Purgstaller C, et al. Differences in brain function and changes with intervention in children with poor spelling and reading abilities. *PloS One*. 2012; 7:e38201. [PubMed: 22693600]
20. Rapp B, Lipka K. The literate brain: the relationship between spelling and reading. *J Cogn Neurosci*. 2011; 23:1180–1197. [PubMed: 20433242]
21. Arbelaez AM, Semenkovich K, Hershey T. Glycemic extremes in youth with T1DM: the structural and functional integrity of the developing brain. *Pediatr Diabetes*. 2013; 14:541–553. [PubMed: 24119040]
22. Perantie DC, Wu J, Koller JM, Lim A, Warren SL, Black KJ, et al. Regional brain volume differences associated with hyperglycemia and severe hypoglycemia in youth with type 1 diabetes. *Diabetes Care*. 2007; 30:2331–2337. [PubMed: 17575089]
23. Gaudieri PA, Chen R, Greer TF, Holmes CS. Cognitive function in children with type 1 diabetes: a meta-analysis. *Diabetes Care*. 2008; 31:1892–1897. [PubMed: 18753668]
24. Silverstein J, Klingensmith G, Copeland K, Plotnick L, Kaufman F, Laffel L, et al. Care of children and adolescents with type 1 diabetes: a statement of the American Diabetes Association. *Diabetes Care*. 2005; 28:186–212. [PubMed: 15616254]
25. American Diabetes Association. Safe at School Campaign Fights On. Legal Advocacy at the American Diabetes Association Update. Fall. 2011 Available at: <http://www.diabetes.org/assets/pdfs/know-your-rights/for-lawyers/legal-advocacy-update-2011.pdf>. Last accessed

What's new?

- Children and young people aged < 23 years with Type 1 diabetes perform less well on verbal intelligence tests than healthy control subjects.
- Subjects with greater exposure to hyperglycaemia had a lower spelling performance than those with less degree of hyperglycaemia exposure.
- Effects on spelling performance were not explained by age, gender, IQ, socio-economic status or blood glucose values at time of testing.

FIGURE 1.

Spelling ability of children and young people with Type 1 diabetes. Participants with Type 1 diabetes with greater hyperglycaemia exposure performed worse (lower score) than those with less hyperglycaemia exposure (higher score) on a spelling test, after controlling for age, gender socio-economic status, verbal IQ and blood glucose levels at the time of testing ($P=0.01$, R^2 change=0.28). Variables shown are standardized residuals.

Table 1

Demographic and clinical information and IQ and academic skills measures

	Controls	Type 1 diabetes	Cohen's d Effect Size
Number of participants	26	61	-
Mean (SD) age, years	15.2 (3.3)	16.2 (3.1; 9–22)	-
Gender: men/women, <i>n</i>	11/15	36/25	-
Mean (SD) total socio-economic status score	40.0 (12.3)	37.4 (18.9; 0–66)	-
Mean (SD; range) diabetes duration, years	-	9.4 (2.6; 5–17.7)	-
Mean (SD; range) age of onset, years	-	6.7 (2.9; 1–13)	-
Median HbA1c mmol/mol %	-	68 8.40 (1.0)	-
Mean (SD; range) number of severe hypoglycaemic episodes per person	-	0.8 (1.8; 0–12)	-
Mean (SD; range) number of diabetic ketoacidosis episodes per person	-	0.44 (0.9; 0–5)	-
Mean (SE) WJIII Verbal IQ scaled score	113.1 (2.6)	106.5 (1.7) *	0.47
Mean (SE) WJIII Spatial IQ scaled score	110.0 (2.0)	107.4 (1.3)	0.24
Mean (SE) WJIII Letter-Word Identification scaled score	103.2 (1.8)	100.8 (1.2)	0.24
Mean (SE) WJIII Calculation Scaled Score	107.6 (2.4)	107.8 (1.6)	0.00
Mean (SE) WJIII Spelling scaled score	109.5 (2.2)	106.0 (1.4)	0.29
Mean (SE) Spelling sensitivity score-word	2.6 (0.04)	2.5 (0.02)	0.46
Mean (SE) percentage of spelling omissions	3.0 (.8)	4.6 (0.5)	0.36
Mean (SE) percentage of 'illegal' spellings	10.5 (1.3)	12.5 (0.9)	0.28
Mean (SE) percentage of 'legal' spellings	13.8 (1.3)	14.4 (0.8)	0.06

WJIII, Woodcock-Johnson III.

Analysis using scaled scores were adjusted for age, gender and socio-economic status.

* $P < 0.05$ for Type 1 diabetes vs control group comparison.