Diabetes, Cognitive Function, and School Performance

By Paula L. Jameson, ARNP, MSN, CDE

In recent years, parents, the diabetes healthcare community, school nurses, and other school personnel have begun providing better support for the needs of students with diabetes during the school day. Important reasons for this support include promoting the students' immediate safety, long-term health and productivity, readiness to learn, and full participation in school activities (National Diabetes Education Program, 2003). Many of the accommodations sought for children with diabetes arise from the need to minimize hypoglycemia and hyperglycemia during the school day and to prevent unnecessary absences. However, even with the best of care, all children with diabetes are susceptible to unanticipated swings in blood glucose levels which may in turn affect performance in academic or extracurricular pursuits.

This article explores and summarizes the current medical literature regarding the impact of diabetes control, specifically hypoglycemia and hyperglycemia, on the neurocognitive function of children with diabetes. Twenty-nine articles (21 studies, 1 meta-analysis [Pacaud, 2002], and 7 reviews) dating from 1989 have been considered. While this body of research is by no means complete or totally conclusive and addresses only children with type 1 diabetes, a thoughtful review should help us to accommodate all students with diabetes and provide them the most rewarding school experience possible.

Review of the Literature

Pediatric diabetes researchers have posed several questions pertinent to school performance. Their questions have included:

- What type of cognitive dysfunction (if any) tends to occur in children with diabetes?
- Are these disturbances associated with either acute or chronic hyperglycemia or hypoglycemia? Are they transient, or lasting?
- At what blood glucose levels does cognitive dysfunction begin?
- How long does it take for cognition to normalize after an episode of hypoglycemia?
- Are there differences in cognitive function between children with type 1 diabetes who have or have not experienced severe hypoglycemic episodes?
- Does the occurrence of hypoglycemic seizures independently predict cognitive dysfunction?
- What other variables explain or confound these relationships—duration of diabetes, age at onset, age of onset of severe hypoglycemia, absenteeism?
- How does poor metabolic control over time affect academic achievement?
- Does lack of symptoms with hypoglycemia worsen cognitive function?

Measuring Cognitive Function in Children with Diabetes

Some of the more common outcomes measured include mental flexibility, reaction time, visuospatial reasoning, short- and long-term memory, attention, IQ (verbal, performance, and/or full-scale), vocabulary, block design, perception, processing speed, executive functions (decision-making), and copying. The wide variety of measurements used makes comparing and synthesizing the data gathered difficult.

Cognitive Domains Potentially Affected in Children with Diabetes

Attention/Concentration
- Focus
- Vigilance
- Mental efficiency

Memory
- Visual
- Recent/Long Term
- Verbal

Language
- Naming
- Comprehension

Intelligence
- Verbal
- Performance
- Full-Scale

Executive Functioning
- Problem-solving
- Abstract reasoning
- Set generation/sequencing
- Mental flexibility

Motor/Psychomotor Speed

Visuo-spatial functioning

Visuoperception

Possible Predictors of Cognitive Dysfunction

To understand the disease-related variables considered predictive of cognitive dysfunction in children with diabetes, it is best to differentiate those that are acute from those that are chronic.

Acute Disease-Related Factors

Most of us are well aware of the acute neurocognitive effects of hypoglycemia, including headache, weakness, irritability, mood changes, confusion, and poor concentration, which are usually experienced when blood glucose levels reach 55 mg/dL (Bode, 2004). Two studies at the University of Pittsburgh demonstrated that in children studied using a controlled hypoglycemic clamp technique, mental efficiency began to decline once blood glucose levels reached the 60–65 mg/dL range and did not normalize until 40–90 minutes after return to euglycemia (Gschwend et al., 1995; Ryan, 1990). Such a decline certainly can cause difficulties for a student

who is trying to take a test, participate in an extracurricular activity, etc. Furthermore, if unrecognized or untreated, these warning signals of hypoglycemia can progress to a more severe state of unconsciousness or seizure requiring the immediate assistance of another individual for treatment. While preventing severe hypoglycemia is inarguably a priority, it is somewhat comforting to read a pilot study by Rankins and colleagues (2005), who followed three subjects (aged 7–10 years) after their first hypoglycemic seizure. They showed significant deterioration 48 hours after the event in several cognitive constructs, with, however, substantial improvement at 6-month follow-up.

Investigators also have examined the impact of severe hyperglycemia, defined as a blood glucose level of 250 mg/dL or higher, on cognition in children with diabetes. These findings have been inconsistent. Davis and colleagues (1996) found that in a small cohort (12 children) studied using a hyperglycemic clamp, performance IQ fell by an average of 9.5% in two-thirds of the children. Gschwend et al. (1995), however, found no effect of hyperglycemia or of rapid return from hyperglycemia to euglycemia upon cognitive performance. Rovet and Alvarez (1997) found that higher blood glucose levels at time of testing were associated with increased difficulty inhibiting impulsive responses on tests of visual attention. The progression of acute hyperglycemia to the extreme state of diabetic ketoacidosis increases the risk of central nervous system damage (and death) and also the possibility of lasting cognitive impairment.

Chronic Disease-Related Factors

In children with early onset of disease, usually defined as less than 5 years of age, researchers have reported poorer performance in many of the aforementioned areas, and poorer school achievement (Desrocher & Rovet, 2004; Puczynski, 1997; Northam, 2001). It is important to note that findings have not always been consistent between researchers. Several have postulated that higher frequency of severe hypoglycemia (particularly seizures) in early childhood may contribute to these deficits (Bjorgaas et al., 1997), but not all studies support this premise (Wysocki et al., 2003; Strudwick et al., 2005). A history of severe hypoglycemia, independent of age of onset, has been reported to be associated with defects in attention components and verbal IQ (Rovet & Alvarez, 1997), verbal short-term memory and phonological processing (Hannonen et al., 2003), and decreased long-term spatial memory (Hershey et al., 2005).

The impact of duration of diabetes upon neurocognitve function has also been studied. Rovet and Ehrlich (1999) found no impairment after 3 years of diabetes on Full-Scale IQ, Verbal and Performance IQ, and the verbal and attention scores. Similarly, they found no difference in school achievement between these children and sibling controls in academic performance. However, Northam (2001) noted statistically significant deterioration in neurocognitve performance both 2 and 6 years after diagnosis when compared to healthy controls on measures of conceptual reasoning, processing speed, memory, and learning.

It can be difficult to differentiate effects of diabetes duration from those of recurrent hypoglycemia, especially in children prone to asymptomatic hypoglycemia, a condition termed "hypoglycemic unawareness." Golden and colleagues (1989) found that children with frequent asymptomatic hypoglycemia had lower scores on copying tasks and abstract reasoning than those with infrequent episodes.

With regard to chronic hyperglycemia, one study found that long-term metabolic control as measured by high long-term hemoglobin A1c (the mean of the average yearly values) predicted a significant decline, first, in performance IQ followed by a decline in verbal IQ (Schoenle et al., 2002). This finding implies that chronic hyperglycemia has deleterious effects on cognitive function. Kaufman et al. (1999) found that mean hemoglobin A1c levels in the 2 years prior to testing correlated negatively with academic achievement and some aspects of verbal memory. Hershey and co-workers (2005) did not find chronic hyperglycemia to have an impact on long-term spatial memory, unlike repeated episodes of severe hypoglycemia as previously described.

Other Pertinent Findings

In the course of cognitive testing, pediatric researchers have made some other interesting discoveries. For instance, Rovet et al. (1997) found that children with early onset of diabetes were more likely to have repeated a grade in school. McCarthy et al. (2003), using a cross-sectional design, studied 244 children with diabetes, and reported lower reading scores and decreased academic scores to be associated with poor metabolic control. Hospitalizations for hyperglycemia and hypoglycemia were both associated with lower achievement scores. However, they found no association of diabetes duration or school absences with academic achievement, but when this same sample was compared with an anonymous classmate control group, they did in fact have more absences. Even more interestingly, though, poor metabolic control correlated with poor academic performance of both the diabetic students and their sibling controls! These findings led the authors to propose that socioeconomic status and behavioral factors may make a stronger contribution to academic achievement than disease-related variables.

Conclusions

In summary, this review suggests the following:

- IQ scores of children with diabetes may be adversely affected by early onset of disease, severe hypoglycemia/hypoglycemic seizures, and/or chronic hyperglycemia.
- Performance on tests requiring intact neurocognitive function, including measures of IQ, can be negatively affected by acute hypoglycemia and perhaps also acute hyperglycemia.
- Memory – visuospatial and verbal – appears vulnerable to the effects of early onset of disease, severe hypoglycemia (especially with seizure), and/or chronic hyperglycemia.
- The acute effects of even mild hypoglycemia on neurocognitive function may be felt for as long as 90 minutes after return to normal blood glucose levels. The effects of severe hypoglycemia, especially involving seizure, may persist for 48 hours or longer.

- Attention – especially selective, focused and inhibitory aspects – appears to be decreased by a history of severe hypoglycemia.
- Academic achievement has not consistently correlated with either duration of diabetes or age of onset but may correlate negatively with poor metabolic control and/or frequency of hospitalizations for hyperglycemia and hypoglycemia.

While we have mentioned other potentially important findings in this article, small sample size and/or lack of replication make it premature to draw further conclusions.

Recommendations

One of the primary goals of clinical research is to improve the overall health of individuals affected by a given disorder. To meet that goal, research findings must be translated into better, safer care. In the case of the student with diabetes, there are several care partners – the diabetes care provider, the school health community, the family, and the student – who can help contribute to better care in the following ways:

- The student's personal healthcare team – by prescribing management plans and modalities that help to minimize hyperglycemia and hypoglycemia while promoting target hemoglobin A1c levels. This includes using technologies to help with the detection of asymptomatic occurrences, especially during sleep.
- School nurses and other school personnel – by providing support for students in monitoring, insulin administration, blood glucose monitoring, nutrition, and management of hyper- and hypoglycemia. Special attention to these should be paid in academic testing situations when the stakes are especially high.
- Family caregivers – by providing the school nurse with a Diabetes Medical Management Plan that outlines the needs of the student during routine school activities and necessary accommodations during test situations. Family care givers should provide the school with necessary supplies to carry out the plan. They should also promote good diabetes control at home to facilitate homework completion and to prevent severe hypoglycemia at school.
- The student with diabetes – by participating in planning meetings as appropriate; by wearing medical alert ID; by addressing hypoglycemia promptly and seeking help when needed; and by following the Diabetes Medical Management Plan.

As pediatric diabetes treatment evolves, all outcomes, including academic success at school, will improve for students with diabetes. The cooperation of the personal health team, school personnel, the family, and the student with diabetes will help make that happen. The school nurse, aided by resources such as the National Diabetes Education Program's guide (2003), plays a crucial role. The well-informed nurse is in an excellent position to inform school personnel, the student, and the family about diabetes, including how to manage it safely and effectively during the school day.

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ABOUT THE AUTHOR

Paula Jameson, ARNP, MSN, CDE is an endocrine nurse practitioner, Certified Diabetes Educator, and Certified Insulin Pump Trainer at the Nemours Children's Clinic, Orlando, Florida. She is a member of the National Diabetes Education Program's Diabetes in Children and Adolescents Work Group.