Factors Associated With Academic Achievement in Children With Type 1 Diabetes

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OBJECTIVE — To examine academic achievement in children with diabetes and to identify predictors of achievement.

RESEARCH DESIGN AND METHODS — Participants were 244 children, ages 8–18 years, with type 1 diabetes. Measures included school-administered standardized achievement tests (Iowa Tests of Basic Skills and Iowa Tests of Educational Development [ITBS/ITED]), grade point averages (GPAs), school absences, behavioral assessment, age at disease onset, hospitalizations, and HbA_{1c}. Statistical differences between subgroups of children were evaluated using *t* test and ANOVA, statistically controlling for socioeconomic status. Regression analyses were carried out to examine predictors of academic performance.

RESULTS — Reading scores and GPA were lower for children with poor metabolic control than for children with average control. Children with hospitalizations for hyperglycemia had lower overall achievement scores than children with better metabolic control and fewer hospitalizations for hyperglycemia. The small group of children with tight metabolic control and hypoglycemic hospitalizations scored particularly low on the ITBS/ITED. Other variables had less clear relationships with academic achievement. Neither early onset of diabetes nor frequent school absence was associated with lower scores on the ITBS/ITED. Sex comparisons found that boys performed better than girls only in math. Socioeconomic status and parent ratings of behavior problems were significantly correlated with academic achievement, but medical variables added only slightly to predictive precision.

CONCLUSIONS — For most children with diabetes, medical variables are not as strongly associated with academic achievement as are factors such as socioeconomic status and behavioral factors. Poor metabolic control and serious hypoglycemia, however, are a potential concern for a subset of these children.

Diabetes Care 26:112–117, 2003

The impact of diabetes on cognitive skills and academic achievement has been unclear. Studies of children with type 1 diabetes generally report that these children have intelligence within the normal range; however, there are several reports of neuropsychological deficits observed in children with diabetes. Difficulties with verbal intelligence (1), memory (2,3), timed motor tasks (4), visuospatial abilities (4–7), abstract/visual reasoning (8), speed of processing (1,5), and attention (3) have all been reported. These findings have been contradictory; some studies have identified verbal and memory difficulties, whereas others have identified visuospatial deficits. Neuropsychological deficits, even when subtle, may place some children with diabetes at risk for academic difficulties. Some studies report that children with diabetes perform academically as well as control groups (9–11), whereas others note reading (3,12,13) and arithmetic (7) deficits. Factors implicated as possible risk factors for neuropsychological difficulties, and therefore achievement problems, include age at onset of diabetes, metabolic control, sex, and psychosocial/behavior problems.

Early onset of diabetes and longer disease duration have been associated with difficulties with visuospatial ability, motor speed, eye-hand coordination (2,4,6), memory (2), attention (3), and achievement (2,4) and poor verbal skills (4). Other studies (14), however, have not found a relationship between neuropsychological functioning and age at onset. Two possible etiologies for the association between early disease onset and cognitive difficulties are that hypoglycemia may affect the developing brain (4) or that chronic hyperglycemia may affect myelination (15).

Frequent fluctuations in blood glucose levels have been identified as a potential risk factor for cognitive deficits. Studies in adults have found chronic hyperglycemia to be associated with decreased verbal skills and reaction times (16,17) and recurrent, severe hypoglycemia to be associated with memory, visuospatial, and motor skills problems (17,18). Studies with children have suggested that frequent asymptomatic hypoglycemia may be associated with slower response rates, abstract/visual reasoning problems, memory difficulties, and a cumulative cognitive effect (8,9,14). After mild hypoglycemic episodes, children's physical recovery rate may be quicker than their cognitive recovery rate, particularly memory and attention (19,20). This is a matter of concern, since episodes of mild hypoglycemia in children may be

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Received for publication 28 February 2002 and accepted in revised form 26 September 2002.

Abbreviations: GPA, grade point average; ITBS, Iowa Tests of Basic Skills; ITED, Iowa Tests of Educational Development; PBS, Pediatric Behavior Scale; PR, percentile rank; SES, socioeconomic status.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

nocturnal and asymptomatic, and therefore unrecognized (21).

Girls with diabetes have been found to have more difficulty with visuospatial tasks (6); boys with diabetes have been found to perform significantly lower on measures of attention and learning (13). However, other studies have noted no sex differences (4), and those differences that have been found may not be related specifically to diabetes (13,14).

It has been suggested that academic problems in children with diabetes are the result of psychosocial problems such as increased school absences (17). Some studies have found that children with diabetes miss significantly more days (7), whereas others have not found absenteeism of children with diabetes to differ from that of the general population (22). Cross-sectional studies of psychosocial adjustment of children with diabetes have found slightly increased behavior problems (23). Longitudinal studies suggest that mood may vary over time, and that internalizing problems noted at diagnosis may resolve by 1 year postdiagnosis but may recur at a later time (24,25).

In summary, there is evidence to suggest that, as a group, children with diabetes perform in the average range on tests of intelligence. However, there are indications of mild, diverse neuropsychological and behavioral difficulties in some children with diabetes that may affect academic performance.

The data reported here are part of a broader study that evaluated the achievement of children with diabetes in comparison to siblings and classmates. That study found that children with diabetes performed as well as either comparison group when group scores were examined (10). The purpose of the analysis presented here is to examine academic performance among subgroups of children with diabetes, and to identify predictors of achievement.

Two specific hypotheses were tested:

- Lower academic performance is associated with age at onset, metabolic control, hospitalizations, sex, and behavioral/emotional adjustment.
- Academic achievement and metabolic control will show an inverse U-shaped relationship, with poor control (frequent hyperglycemia) and excessively tight control (frequent hypoglycemia) associated with achievement problems.

RESEARCH DESIGN AND METHODS

Sample/setting

Participants were children followed for type 1 diabetes at five clinics in a rural Midwestern state. Children were diagnosed with diabetes for at least 1 year, were 8–18 years old, and had no other chronic health conditions except thyroid problems. Approval by the Institutional Review Board was obtained. Of 408 potential subjects, 244 (60%) participated. At the primary site, a nurse enrolled 164 of 213 potential subjects (77%). At collaborating sites, families were contacted by mail and 80 of 195 (41%) participated. The number of children with diabetes in this article is greater than the number in the broader study (10) because children with diabetes who did not have a classmate or sibling were not included in the broader study analyses.

Participants included 130 boys and 114 girls with a mean age of 14.8 ± 3.2 and a mean school grade of 8.1 ± 2.9. The mean age of diabetes onset was 8.3 ± 3.7 years, and the mean disease duration was 7.1 ± 3.9 years. The Hollingshead two-factor index (26) revealed that children were primarily from middle- to upper-middle-class families, which is typical for this state. Minority representation in this state is <6%.

Measures

Information collected from parents included school data for current academic year, parents' education and occupation, and perceptions of diabetes impact on psychosocial problems. Diabetes data from medical records included metabolic control (mean HbA_{1c} values for current year), number of hospitalizations, and age at onset of diabetes.

Academic achievement was assessed through grade point averages (GPAs) and standardized achievement batteries administered to most children in this state, the Iowa Tests of Basic Skills (ITBS) (27) in grades 3–8 and the Iowa Tests of Educational Development (ITED) (28) in high school. Scores on three broad subject areas were examined: math, reading, and core total (a composite of math, reading, and language). National percentile ranks (PRs) of the ITBS/ITED scores were transformed to a standard score with a mean of 100 and a standard deviation of 15. Students in this state tend to score above the national average, with a median national PR equal to a standard score of 106 across grades 3–11. School marks were converted to a common scale ranging from 0 to 4, with 0 equal to very poor or F marks and four equal to excellent or A marks to estimate GPA. GPA showed a median correlation of 0.71 with achievement test scores across grades 3–12. From school records, days absent were recorded as a cumulative number for each year.

A short, 50-item screening form of the Pediatric Behavior Scale (PBS) (29) was used to obtain information on characteristics of child behavior. The PBS is a rating scale, completed by parents, that was developed to evaluate behavior problems of children 6–16 years of age. The PBS-50d includes 30 items covering four major areas of behavioral/emotional adjustment: aggression/opposition (nine items), hyperactivity/inattention (nine items), depression/anxiety (seven items), and physical complaints (five items). Twenty additional diabetes-specific items were added to assess mood variability (four items), noncompliance (six items), fatigue (three items), and learning (seven items) (10). Reliability, as measured by coefficient alpha, ranged from 0.75 for fatigue to 0.89 for hyperactivity/inattention and depression/anxiety, with a median coefficient of 0.86.

RESULTS — A cross-sectional approach was used to evaluate current academic achievement. Preliminary analyses revealed that socioeconomic status (SES) was significantly correlated with the ITBS/ITED (core total, $r = 0.37$, $P < 0.0001$), indicating that higher SES was associated with higher academic performance. Therefore, SES was controlled in subsequent analyses. The numbers of children in each analysis vary due to individual missing data.

Hypothesis 1

Age at onset. Children were divided into two groups based on age at diagnosis. ITBS/ITED scores, GPAs, and school absences were compared between children with early onset (diagnosed before age 5 years) and late onset (diagnosed at or after age 5 years). The average age of onset in the early-onset group was 3.1 ± 1.3 years ($n = 48$), and in the late-onset group, 9.7 ± 2.8 years ($n = 186$). The mean grade was 7.1 ± 3.1 for the early-onset group and 8.4 ± 2.7 for the late-onset

Table 1—*ITBS/ITED achievement scores and school performance based on metabolic control*

	Good control, HbA$_{1c}$ < 8%	Average control, HbA$_{1c}$ 8–10%	Poor control, HbA$_{1c}$ >10%
Reading			
Mean ± SD	112.1 ± 16.1	110.1 ± 12.0	105.7 ± 12.9*†
n	36	110	56
Math			
Mean ± SD	113.0 ± 14.5	111.8 ± 13.3	109.1 ± 15.9
n	38	109	55
Core total			
Mean	113.1 ± 15.2	111.0 ± 12.7	106.7 ± 15.5*
n	36	105	53
School absences			
Mean	7.2 ± 7.7	7.9 ± 7.4	9.2 ± 8.2
n	47	121	50
GPA			
Mean	3.1 ± .7	3.1 ± .7	2.8 ± .8*†
n	45	119	54

Data are least squares means controlling for SES. *Statistically different ($P < 0.05$) from the good control group. †Statistically different ($P < 0.05$) from the average control group.

group. No statistically significant differences were found between the two groups on ITBS/ITED performance, absences, or GPA when controlling for SES.

Metabolic control. Children were divided into three groups based on current metabolic control: good control (HbA$_{1c}$ <8%), average control (HbA$_{1c}$ 8–10%), or poor control (HbA$_{1c}$ >10%) (Table 1). Comparisons of ITBS/ITED performance between the three groups found that children in the poor-control group performed significantly worse than those in the good-control group on reading, core total, and GPA and than the average-control group on reading and GPA.

Hospitalizations related to diabetes. Based on medical records, hospitalizations for hyperglycemia, beyond the initial hospitalization, occurred in 37 children; hospitalizations for hypoglycemia occurred in 21 children. Comparisons were made between groups of children: children with none or only the initial hospitalization due to hyperglycemia ($n = 148$), children hospitalized two or more times due to hyperglycemia ($n = 32$), and children hospitalized one or more times due to hypoglycemia ($n = 16$). To assess the unique impact of hospitalization due to either hyper- or hypoglycemia, comparisons excluded data from five children who were hospitalized for both. Children hospitalized for hyperglycemia performed significantly worse ($P < 0.05$) on math (107.4 ± 13.5) than children who did not have additional hospitalizations (114.2 ± 13.8). Children hospitalized for hypoglycemia performed significantly worse ($P < 0.05$) on core total (104.6 ± 16.0) than children who did not have additional hospitalizations (112.8 ± 13.4).

Additional analyses looked at core total data when children were divided into groups based on both number of hospitalizations and current metabolic control (Table 2). Separate analyses were completed for hyper- and hypoglycemia hospitalization groups. In the group hospitalized for hyperglycemia, children with poor metabolic control performed significantly worse than children who had good or average metabolic control and no more than one hospitalization. In the group never hospitalized for hypoglycemia, children with good metabolic control performed significantly better than children with poor control. An interesting finding in the children who had been hospitalized for hypoglycemia was that the three children who had good metabolic control performed below all the other groups of children with diabetes. Whereas the ITBS/ITED analyses were carried out on all three subject areas, only the results for core total are presented be-

Table 2—*Mean achievement scores for children based on level of metabolic control and history of hospitalizations*

Metabolic control*	Hyperglycemia: Hospitalizations ≤ 1	Hyperglycemia: Hospitalizations ≥ 2	Hypoglycemia: Hospitalizations = 0	Hypoglycemia: Hospitalizations ≥ 1
Good				
Mean ± SD	114.2 ± 15.3	105.8 ± 17.8	115.5 ± 14.4	90.4 ± 5.8†‡§‖
n	31	4	32	3
Average				
Mean ± SD	111.5 ± 12.7	111.7 ± 11.4	111.3 ± 12.7	113.3 ± 11.3
n	78	16	83	11
Poor				
Mean ± SD	110.0 ± 14.5	101.2 ± 15.0¶#	108.9 ± 14.1†	107.8 ± 18.8
n	38	11	42	5

Data are least squares means for ITBS/ITED core total scores, controlling for SES. *Good control, HbA$_{1c}$ <8%; average control, HbA$_{1c}$ 8–10%; poor control, HbA$_{1c}$ >10%. †Significantly different from good control and hospitalizations = 0 ($P < 0.05$). ‡Significantly different from average control and hospitalizations = 0 ($P < 0.05$). §Significantly different from poor control and hospitalizations = 0 ($P < 0.05$). ‖Significantly different from average control and hospitalizations ≥ 1 ($P < 0.05$). ¶Significantly different from good control and hospitalizations ≤1 ($P <0.05$). #Significantly different from average control and hospitalizations ≤ 1 ($P < 0.05$).

Table 3—*Bivariate correlations of background, medical, and behavioral variables with ITBS/ITED core total scores and intercorrelations among covariates*

	Core total	Sex	SES	Absences	Hyper	Hypo	Age at onset	HbA$_{1c}$
Background								
Sex	−.07 (220)	1.00	—	—	—	—	—	—
SES	−.37 (215)*	.07	1.00	—	—	—	—	—
Absences	−.07 (211)	.07	.08	1.00	—	—	—	—
Medical								
Hyper	−.14 (201)*	.13*	.14*	.30*	1.00	—	—	—
Hypo	−.19 (200)*	.10	.00	.10	.08	1.00	—	—
Age at onset	.04 (214)	−.02	.03	.06	−.07	−.14*	1.00	—
HbA$_{1c}$	−.21 (166)*	.03	.06	.20*	.21*	.05	−.17*	1.00
PBS Scales								
Aggression	−.29 (215)*	−.11	.13*	.19*	−.03	.01	−.03	.19*
Hyperactivity	−.36 (217)*	−.20*	.21*	.07	−.05	.06	.02	.15*
Depression	−.20 (213)*	.01	.04	.21*	.04	.05	.01	.15
Physical	−.16 (218)*	.06	.17*	.30*	.21*	.10	−.03	.11
Variability	−.25 (218)*	−.04	.15*	.26*	.07	.06	−.03	.18*
Compliance	−.22 (215)*	−.02	.03	.25*	.10	.10	.06	.33*
Fatigue	−.11 (217)	−.01	.03	.24*	.01	−.04	.16*	.16*
Learning	−.53 (217)*	−.14*	.19*	.24*	.04	.12	.06	.19*

Hyper, number of hospitalizations due to hyperglycemia; Hypo, number of hospitalizations due to hypoglycemia. *Significantly different from 0 ($P < 0.05$).

cause results were similar for each subject area. Both math and reading were highly correlated with core total ($r = 0.92$ for each).

Documentation of hypoglycemia, other than episodes requiring hospitalization, was not consistently recorded in patient records. Further, the severity and duration of hypoglycemia, including the presence of seizures, was not documented well enough to include in these analyses.

Sex. There were no significant differences due to sex in reading (boys, 109.7 ± 12.9; girls, 108.5 ± 14.3) or core total (boys, 110.8 ± 14.0; girls, 109.6 ± 14.7). Performance differed significantly ($P < 0.03$) only in math, where boys (113.5 ± 13.8) performed better than girls (109.3 ± 14.3). There were no significant differences in school absences (boys, 7.7 ± 7.2; girls, 8.6 ± 9.1) or GPA (boys, 3.0 ± 0.7; girls, 3.1 ± 0.8).

Days absent. The mean absence rate was 8.1 ± 8.1 days per year. To identify an expected school absence rate, the mean absence rate of siblings of children with diabetes from the broader study (5.3 ± 4.7 days) was used. Children with diabetes were divided into two groups, those with 10 or more absences in the current school year (>1 SD above the sibling mean) and those with fewer than 10 absences. No statistically significant differences were found on ITBS/ITED scores or GPA.

Behavior. When parents were asked about their perceptions of the impact of diabetes on psychosocial problems, 18% believed diabetes caused learning problems, 18% believed diabetes caused behavior problems, and 32% believed diabetes caused mood problems. Children identified by their parents as having current learning, mood, or behavior problems performed significantly worse on core total compared with children without problems. Both groups, however, performed within 1 SD above the mean on all ITBS/ITED scales. All PBS-50d factors, except fatigue, were significantly correlated with core total (Table 3), and all PBS-50d factors were significantly correlated ($P < 0.05$) with GPA.

Predictors of academic performance. Regression analyses were carried out to identify the best predictors of academic performance, defined by core total and GPA. Variables significantly correlated ($P < 0.05$) with core total (Table 3) were SES, number of diabetes-related hospitalizations, HbA$_{1c}$, and all PBS-50d scales except fatigue. The PBS-50d learning subscale was the variable with the highest correlation with both core total ($r = -0.53$) and GPA ($r = -0.61$). This was expected, since the learning subscale is a reflection of the parent's perception of the child's school performance and is therefore not independent of actual performance.

Many of the independent variables were intercorrelated, and therefore initial model fitting was conducted separately for background variables (sex, SES, and school absences), medical variables (hospitalizations due to hyper- and hypoglycemia, HbA$_{1c}$, and age at disease onset), and PBS-50d variables (eight subscales). The correlations among the independent variables are given in Table 3. An ordinary multiple regression model using core total as the dependent variable was carried out for the background variables ($R^2 = 0.11$), where SES ($\beta = -0.62$) was the only variable found to be significant ($P < 0.0001$). A second regression equation with core total as the dependent variable used only the medical variables ($R^2 = 0.07$). None of the four medical variable regression coefficients was significant. A third regression was carried out to predict core total using only the PBS-50d subscales ($R^2 = 0.29$). Of these, learning ($\beta = -23.55$) and fatigue ($\beta = 9.52$) were the only variables with significant coefficients ($P < 0.05$). A fourth regression model was carried out incorporating the variables found to be significant in the three prior regressions. This final regression model included the independent variables SES ($\beta = -0.54$), fatigue ($\beta = 9.55$), and learning ($\beta = -24.75$) ($R^2 = 0.38$), which all had significant coefficients ($P < 0.01$).

The bivariate correlations between

GPA and the independent variables were similar to those for core total. Those that were significant ($P < 0.05$) included SES ($\rho = -0.30$), absences ($\rho = -0.27$), hospitalizations due to hypoglycemia ($\rho = -0.15$), HbA_{1c} ($\rho = -0.21$), and all PBS-50d scales (ranging from -0.27 for fatigue to -0.61 for learning). Regression analyses were carried out for the background, medical, and PBS-50d subscale variables using GPA as the dependent variable. The regression equation using background variables ($R^2 = 0.17$) found SES ($\beta = -0.02$) and school absence ($\beta = -0.03$) coefficients to be significant ($P < 0.05$). Unlike core total, the second regression, using medical variables to predict the dependent variable GPA ($R^2 = 0.08$) produced three significant coefficients ($P < 0.05$): hospitalizations due to hypoglycemia ($\beta = -0.27$), age at onset ($\beta = -0.03$), and HbA_{1c} ($\beta = -0.08$). The third regression equation using only PBS-50d scales to predict GPA ($R^2 = 0.41$) resulted in significant coefficients ($P < 0.05$) for the fatigue ($\beta = 0.22$) and learning ($\beta = -0.83$) scales. A final regression equation to predict GPA was carried out using the independent variables that were significant in each of the separate regressions for background, medical, and PBS-50d subscales. The final model for GPA included the independent variables SES, absences, number of hospitalizations due to hypoglycemia, age at onset, HbA_{1c}, fatigue, and learning ($R^2 = 0.44$), and of those, SES ($\beta = -0.01$) and learning ($\beta = -0.70$) had statistically significant regression coefficients ($P < 0.001$) in the final model.

As noted earlier, the PBS-50d learning scale is highly correlated with both core total and GPA. If learning is excluded from the regression analysis, however, the percentage of explained variance is reduced, but similar background and medical variables are significant.

Hypothesis 2

A separate regression incorporating a quadratic term was carried out and plotted between ITBS/ITED scores and HbA_{1c}, with an expectation of finding an inverse U-shaped relationship with both frequent hyperglycemia and frequent hypoglycemia associated with lower achievement. The relationships between academic achievement and HbA_{1c} did not show an inverse U-shaped relationship as was hypothesized ($R^2 = 0.03$, $P < 0.06$). In the scatter plots and regression analyses, a trend was noted for children with good metabolic control to perform better academically than children with poor metabolic control. The relationships were similar for reading, math, core total, and GPA. In Table 2, however, where children are grouped by both metabolic control and hospitalization history, there is a trend toward the hypothesized relationship. For children with histories of increased hospitalizations, those with average metabolic control tend to perform better than those with either good or poor control.

CONCLUSIONS — In this large sample of children with type 1 diabetes, lower academic performance was associated with poorer metabolic control. Specifically, children with HbA_{1c} levels $>10\%$ differed from children with either average control (HbA_{1c} 8–10%) or good control (HbA_{1c} $<8\%$) in both reading achievement and overall GPA, but not in the number of school absences. These differences were significant even when statistical adjustments were made for differences due to SES. It was not clear from these data, however, whether the cognitive effects of poor metabolic control caused the lower achievement or whether children with better academic skills were also more effective at managing their diabetes. The latter interpretation seems more likely given the fact that a subset of the children with high HbA_{1c} levels did not differ in achievement from their nondiabetic siblings in the broader study (10). However, further study is needed to clarify this given earlier findings of neuropsychological difficulties.

Children whose poor management of blood glucose levels resulted in hospitalizations for hyperglycemia had lower overall ITBS/ITED scores than children with better metabolic control and fewer hospitalizations for hyperglycemia. This is an interesting phenomenon given earlier findings of persistent electroencephalograph abnormalities after hospitalization for hyperglycemia and/or diabetic ketoacidosis in children with diabetes (30). With regard to hospitalizations for serious episodes of hypoglycemia, the small group of children with tight metabolic control and hypoglycemic hospitalizations scored particularly low on the ITBS core total. Thus, while good control tends to be associated with higher academic achievement overall, there are some children with good control who are at risk for academic problems in association with serious hypoglycemia. The numbers of subjects in several of these comparisons were quite small, which emphasizes the need for more research in this area.

Other variables had less clear relationships with academic achievement. Early onset of diabetes was not associated with lower scores on the ITBS/ITED. Sex did not have a significant effect on achievement in reading or core total for these children. Boys performed significantly better in math, however, a pattern that may not be directly related to diabetes (31).

In examining combinations of variables that were predictive of academic performance through regression analyses, medical variables alone were not highly predictive of either test scores or GPA. Because SES and parent ratings of behavior problems were significantly correlated with academic achievement, medical variables added only slightly to predictive precision. Bivariate correlations between medical variables and either core total scores or GPA ranged from -0.21 to 0.04. However, medical variables had a somewhat greater influence on GPA than on ITBS/ITED, as seen in the regression models. Medical variables may affect daily performance more than overall achievement. We chose to use both test scores and GPA as measures of academic achievement. Although GPA has the potential for unreliability due to differences in teacher grading practices, the high correlation between GPA and core total and the fact that other significant correlations were found mediated this concern.

Although some children with low achievement may have chosen not to participate in this study, the overall findings suggest that medical variables have less effect on academic achievement than do factors such as SES and behavior problems for most children with diabetes. However, better metabolic control is associated with better academic performance, although the direction of causation is not clear. Of greatest concern is the likelihood that a small but significant subset of children with diabetes are at high risk for serious hypoglycemia, especially when on an insulin regimen that promotes tight metabolic control. Close monitoring of these high-risk children should be a priority in minimizing long-term cognitive effects of diabetes and its treatment.

Acknowledgments— This study was funded by the National Institute of Nursing Research, National Institutes of Health (R15 NR04218). We are indebted to the following institutions: Blank Children's Hospital, Des Moines, Iowa; Children's Hospital of Iowa, Iowa City, Iowa; McFarland Clinic, Ames, Iowa; Pediatric Center, Cedar Rapids, Iowa; and the University of South Dakota, Sioux Falls, South Dakota.

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