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Use of continuous glucose monitoring in young children with type 1 diabetes: Implications for behavioral research

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Abstract

Objective—This study presents data on the use of continuous glucose monitoring (CGM) in young children with type 1 diabetes mellitus (T1DM). CGM provides moment-to-moment tracking of glucose concentrations and measures of intra- and interday variability which are particularly salient measures in young children with T1DM.

Methods—Thirty-one children (M age = 5.0 years) with T1DM wore the Medtronic Minimed CGM for a mean of 66.8 hours. The CGM was inserted in diabetes clinics and parents were provided brief training.

Results—Few difficulties were experienced and families cited the acceptability of CGM. Participants' CGM data are compared to self-monitoring blood glucose (SMBG) data as well as data from older children with T1DM to illustrate differences in methodology and variability present in this population. CGM data is used to calculate glucose variabilty, which is found to be related to diabetes variables such as history of hypoglycemic seizures.

Conclusions—CGM is an acceptable research tool for obtaining glucose data in young children with T1DM and has been used previously in older children and adults. CGM may be particularly useful in young children who often experience more glucose variability. Data obtained via CGM is richer and more detailed than traditional SMBG data and allows for analyses to link blood glucose with behavior.

Keywords

type 1 diabetes mellitus; adherence; technology; continuous glucose monitoring

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Introduction

Blood glucose concentrations are an important measure of health outcomes in type 1 diabetes (TIDM) and provide patients valuable feedback pertaining to their diabetes management and relative risk for diabetes-related complications (1,2,3). Traditional measures of glucose levels include hemoglobin A1c (HbA1c) and self-monitored blood glucose levels. HbA1c provides a measure of the average glucose concentration over a 2 to 3 month time period (1). Self-monitored blood glucose (SMBG) levels provide patients and health care providers with real-time snapshots of glucose levels at specific time points (e.g., before meals, at bedtime).

Continuous glucose monitoring (CGM) is a relatively new technique for measuring glucose levels in patients with T1DM and has been used for clinical and research purposes. CGM provides a measure of glucose concentrations every 5 minutes, yielding a more complete picture of glycemic excursion that is free of bias related to the timing or frequency of testing. CGM also provides moment-to-moment information about glucose level variability in contrast to data on mean glucose concentrations (as with HbA1c data) and isolated observations of glucose levels (as with SMBG data). Recently, evidence has begun to suggest that glucose variability is a key factor in the risk for diabetes-related complications. For example, higher levels of variability have been shown to predict increased microvascular complications in adults with T1DM (4,5,6). For young children with T1DM, in particular, glucose variability is an important consideration. Given the small insulin doses required for young children, their varying activity levels, and their often unpredictable eating habits, glucose levels often fluctuate widely on a daily basis despite parent and health care professionals' best efforts to maintain euglycemia (7,8). CGM provides a method to more accurately measure glucose variability given the continuous nature of the data obtained. While CGM has been used in clinical care and research with older children and adolescents with T1DM (9,10,11); to date, there have been few studies focusing on glucose variability in young children with T1DM and the use of CGM technology in this population has been limited (12,13).

In this brief report we present data evaluating the acceptability and benefits of using CGM in a sample of young children with TIDM and the ways in which these data may be particularly useful for behavioral health researchers. In addition, this study seeks to provide data on the variability of glycemic levels in young children with T1DM, given that in this population patterns in glucose variability may be more meaningful to examine than traditional measures of glycemic control such as HbA1c and SMBG. Finally, we examine the relations between CGM data and diabetes-related behavioral variables to provide evidence that continuous glucose data can be linked to more traditional measures of diabetes care.

Methods

Participants

Participants were 31 children aged 2 to 7 years with TIDM and their caregiver(s) recruited during an outpatient diabetes clinic visit at two children's hospitals in the Midwestern United States in 2006 and 2007. In order to be eligible for the current study, children were required to be between the ages of 2 to 7 years, have been diagnosed with T1DM for at least one year, and must have used an insulin pump for diabetes management for a minimum of 6 months. The mean age of children participating was 5.0 years (*SD* = 1.3) and majority of children were male (*n* = 17) and Caucasian (*n* = 30). Children participating in this study reported a mean length of time with diabetes of 2.28 years (SD = 0.84). Participating parents were primarily mothers (*n* = 30), 65% had obtained a college degree, and socio-economic status, based on Hollingshead Four-Factor Index (14), was as follows: I (Lowest level) =

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0%, II = 10%, III = 14%, IV = 48% and IV (Highest level) = 28%. Out of 47 eligible families approached, 37 agreed to participate. Parents who declined participation cited scheduling issues, child anxiety related to CGM use, and concern about limitations to their child's activities. Six families withdrew before initiating the protocol because the child aged out of the study, the family missed the study appointment, or because the research team was unable to reinitiate contact with the family.

Procedure

Data reported are part of a larger investigation of the relations between child nutrition, behavior, and blood glucose levels. Institutional Review Board (IRB) approval was obtained prior to recruitment. Eligible families were identified through database review and contacted via mail with information about the study. Families were provided with an opt-out postcard to return by mail if they did not want to be contacted by a member of the research team. Families who did not return the opt-out postcard were contacted by phone or at their next clinic visit to ascertain their interest in study participation. Families agreeing to participate signed a written informed consent before completing study activities. CGM sensor insertion occurred in the diabetes clinic and was performed by trained study personnel. A topical anesthetic was used if desired by families (EMLA Cream, Astra Pharmaceuticals, Wayne, Pa, $n = 23$). During the visit, parents were trained on the use and calibration of the CGM according to guidelines outlined by the manufacturer. The total time required for an insertion visit averaged 60 minutes including parent training. At the end of the monitoring period, parents could return to clinic to remove the sensor or remove the sensor at home and a member of the research team picked up the monitor from the family. Self-Monitoring Blood Glucose (SMBG) data were downloaded from each child's BG meter. Data were downloaded coinciding with the CGM monitoring period and participants had a mean of 14 days of SMBG data. CGM data were downloaded using the MiniMed Solutions Software version 2.0b (Northridge, CA). Parents were sent by mail a copy of their child's retrospective CGM data upon study completion.

Measures

Minimed Continuous Glucose Monitoring System Gold® (CGM)—The CGM is an innovative and relatively non-invasive device which measures glucose concentrations over a continuous 72-hour period. The sensor is placed just under the skin using a spring-loaded insertion device, usually in the abdomen, hip, or buttocks. Glucose concentrations in the interstitial fluid are measured every 10 seconds. Using a computer-driven algorithm, the sensors relate the subcutaneous interstitial fluid glucose measurements to capillary BG concentrations and the average of these data are stored in the sensor's memory every five minutes. The monitor is approximately 9 × 7 × 2 cm, weighs approximately 4 ounces, and easily clips to clothing or can be placed in a pocket. A waterproof pouch must be worn over the monitor during bathing or showering as it cannot be disconnected without data loss. As this study was observational in nature, the decision was made to use a retrospective CGM device rather than a real-time CGM, which in providing real-time glucose information, could have prompted parents to make changes in their child's diabetes regimen resulting in an unintended intervention.

Medical history form—Parents completed a 25-item questionnaire (15) about weekly diabetes behaviors such as omitting insulin doses (e.g., “how often do you omit insulin for your child at meals/snack?”), forgetting insulin boluses (e.g., “how many times per week do you forget to bolus your child at meals/snacks?”), and eating behaviors (e.g., “how many snacks does your child eat each day?”). Parents responded to each item with an estimate of how often this behavior “typically” occurred. This form also contained items about diabetes-related variables such as duration of T1DM and history of hypoglycemic seizures.

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Glycemic control—Glycemic control was measured with glycosylated hemoglobin A1c (HbA1c), the gold standard assay measuring health status in diabetes care. HbA1c represents the average BG level over the preceding 8–12 weeks, with higher values indicating poorer glycemic control. Participants' HbA1c value at the time of enrollment or their most recent prior HbA1c was obtained through chart reviews. HbA1c tests were processed using the DCA 2000 at both study sites. Mean HbA1c for participants was 7.7% (*SD* = .68), which is within the ADA published target of less than 8.5% for children under age 7 (1).

Results

Glucose Data

Overall, participants in the study had a mean of 66.8 hours of CGM data (range = 24–79 hours). The mean percent time within range (80–180 mg/dl) for CGM data for all participants was 44% (*SD* = 16%, range = 12–74%). Participants' mean percent time below range was 5% (*SD* = 5%, range = 0–19%) and mean percent time above range was 51% (*SD* = 17%, range = 20–88%). The mean glucose concentration via CGM was 191 mg/dl (*SD* = 39, range = 121–273) while the mean SMBG reading during the monitoring period was 195 mg/dl (*SD* = 92, range = 134–273). A paired sample t-test indicated no difference in mean glucose obtained via CGM and SMBG. A pearson correlation showed a high degree of association between the two measures suggesting reliability among the measures ($r = 0.72$, $p \leq .000$). Children's CGM and SMBG data are presented in Table 1.

In addition to obtaining mean glucose values, further calculations were conducted using children's CGM data. Each participant's intraday glycemic variation was calculated using the continuous overall net glycemic action (CONGA) statistic (16). CONGAn represents the standard deviation of differences between the current observation and the observation n hours prior (i.e., CONGA1 = 1 hour prior, CONGA 2 = 2 hours prior, CONGA4 = 4 hours prior). The specific time intervals of 1, 2, and 4 hours are used as these periods are hypothesized to be approximate times between snacks and meals. Higher CONGAn values represent more glucose variability, which suggests poorer glycemic control within a 24 hour period. Published reports suggest that adults without T1DM have mean CONGA1, COGNA2, and CONGA4 values of 13, 15, and 18 mg/dl, while older children and adolescents with T1DM have values of 44, 64, and 83, respectively (16). Participants in the current study had mean CONGA1, COGNA2, and CONGA4 values of 58 (*SD* = 8), 83 (*SD* = 11), and 105 mg/dl (*SD* = 15), respectively (Table 1). We compared previously reported glucose variability values with our current data using one sample t-tests (Table 2). There were significant differences in glucose variability between older children with T1DM (16) and young children with T1DM in the current study based on CONGA 1 (t (30) = 8.67, $p \leq .000$), CONGA 2 (t (30) = 9.05, $p \leq .000$) and COGNA4 (t (30) = 7.45, $p \leq .000$) values. Results suggested that younger children in the current sample had more glucose variability than older children with T1DM.

Children's inter-day glycemic variation was calculated using the Mean Daily Differences (MODD) statistic. MODD is equal to the mean absolute value of the difference between glucose values taken on two consecutive days at the same time. Higher MODD values may indicate poorer glycemic control across multiple days and/or a more irregular daily schedule. Table 1 lists MODD statistics for each participant. One sample t-tests comparing current MODD scores with MODD scores reported previously (16) suggested differences in interday glucose variability that approached significance (t (30) =2.00, $p = .057$). Younger children with T1DM were found to have greater interday variability in their glucose levels than adolescents with T1DM (Table 2).

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Relation between CGM and diabetes-related variables

Final analyses examined the relationship between CGM statistics (average CGM value, MODD, and CONGAn) and the diabetes-related adherence variables: number of omitted insulin dosages at meals or snacks per week, daily blood glucose monitoring frequency, and number of meals or snacks per day. Pearson *r* correlations were used for these analyses. Results suggested a significant negative correlation between average CGM value and parent-report of omitted insulin dosages at meals/snacks ($r = -.371$, $p \leq .04$). Mean CGM value was positively correlated with HbA1c ($r = .387$, $p \leq .03$) but mean SMBG was not. Other relationships were not significant. Additionally, *t*-tests were conducted to determine differences in CGM statistics based on parent report of child experiencing a hypoglycemic seizure (yes versus no). Children who had experienced at least one hypoglycemic seizure ($n = 8$) had higher CONGA2 values ($M = 91.7$) than those who had not experienced a seizure ($M = 81.5$; $t\ (28) = 2.0$, $p \leq .05$). Children who had experienced at least one hypoglycemic seizure also had higher CONGA4 values ($M = 118.4$) than those who had not experienced a seizure ($M = 101.7$; $t\ (28) = 2.5$, $p \leq .04$).

Discussion

The current study provides information regarding the type of data that can be obtained using CGM technology in young children with T1DM. In particular, the use of calculations for intra- and inter-daily variations, such as CONGA and MODD, can provide a more complete and accurate picture of participants' glucose levels than traditional measures of glycemic control. Participants in this study had greater glucose variability, as assessed by CONGAn and MODD, than adults without T1DM and older children and adolescents with T1DM, as would be expected given the challenges of maintaining euglycemia in young children with this condition. This finding supports the assertion that young children are more likely to experience extreme glucose variability. This is likely due to a number of factors including heightened insulin sensitivity, fluctuating activity levels, and erratic eating behaviors (7,8) and this may place these young children at-increased risk for diabetes-related complications in the future (4,5,6). It also suggests that glucose variability may be an important measure of glycemic control to study in this young population and target through intervention.

In the current study, we were also able to link measures of glycemic control and variability with diabetes-related variables. Our results suggest that children with a history of hypoglycemic seizures have increased glycemic variability and this finding echoes results found in older individuals with T1DM (4). This may indicate these children have generally more fluctuating glucose levels, making seizures more likely. We also found that higher frequency of omitted meal boluses was related to lower mean CGM values. This finding may be explained by parents of children, with typically lower glucose levels, more frequently omitting the meal or snack insulin bolus due to hypoglycemia. Interestingly, our data shows a relation between HbA1c and mean CGM values but not with SMBG values. This finding supports the assertion that the use of SMBG data as a proxy for glycemic control may be ineffective. Given that SMBG data are highly dependent on the frequency and timing of BG checks (e.g., before meals, when they believe the child has a high or low glucose), it may not provide an accurate representation of overall glycemic control. Overall, our results suggest that utilizing CGM technology and the calculation of glycemic variability statistics can provide a richer, more accurate picture of young children's glucose levels. In contrast, SMBG data may not link with glycemic control in this population and the singular use of HbA1c values may mask important patterns in glucose variability which could impact overall glucose levels.

In addition to these benefits, there are a number of potentially exciting and novel uses of CGM data for behavioral researchers. For example, intra-daily measurement can provide

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useful data about how often or rapidly glucose levels are changing. In the future, researchers may be able to link daily variability to constructs such as neurocognitive functioning, behavior, mood, or even diabetes-specific factors such as fear of hypoglycemia. Inter-daily measurement of glucose variability provides researchers with the potential to document the impact of interventions targeting glucose control at a more refined level rather than only documenting mean change in glucose levels (i.e., HbA1c). For instance, researchers may be able to track how adherence to behavioral interventions impacts glucose variability on a day-to-day basis and if the interventions can lead to more stable improvements in glucose variability. Furthermore, CGM data can be used to test relations between psychological or behavioral constructs with specific time periods of interest, such as post-prandial glucose levels, overnight glucose levels, or the frequency of undetected hypoglycemic events. In older children, researchers have begun to examine the relations between child mood, behavior, and CGM data. McDonnell and colleagues (17) utilized CGM technology in school-age children with T1DM. These researchers found that higher frequencies of externalizing behavior were related to greater length of time above the target glucose range. To our knowledge, this is the only study that has examined the link between behavior and CGM data in children, thus the potential for future work in this area is great.

The current study also demonstrates the feasibility of using CGM in young children with T1DM. Anecdotally, families in the current study were excited about participation and frequently cited the benefit of the retrospective CGM data in terms of improving their child's diabetes care. Two families in the study experienced insertion difficulties; however, they each opted to undergo a second insertion on the same day. While the manufacturer's instructions report that mild irritation at the insertion site is possible, participants in the current study did not experience this or other adverse events.

Despite the wealth of data provided by CGM, there are obstacles to widespread use in research. In the current study, some participants displayed anticipatory anxiety about the insertion which could hinder research participation. Additionally, CGM is vulnerable to malfunctions and misuse. Eight families experienced minor difficulties including two insertion problems, one sensor failure, one CGM monitor failure, and four parent mismanagement issues (e.g., parents not entering SMBG data required for calibration). Depending on the type of difficulty encountered some loss of data may occur. Based on our experience, we recommend planning for 5–10% more participants than needed in order to account for unexpected data loss. Finally, while CGM has been used successfully in the current study and two other research protocols (17,18), it is not currently approved by the FDA for use in children under seven years old, which may create an obstacle when seeking institutional approval for research.

There are several limitations of the current study. While it is notable that associations were found despite the small sample size, additional participants could provide increased power to detect other associations of interest. The study only recruited children using an insulin pump. Thus, the ability to generalize the results to a conventionally-managed population may be limited. In addition, it would be useful for future studies to incorporate objective measures of diabetes management behaviors (e.g., insulin omission, carbohydrate intake) which could be linked with CGM data. Finally, in this study families did not provide standardized feedback about their experience with the CGM technology. Therefore, feasibility data presented are anecdotal. It would be useful for future work to incorporate standardized measures of acceptability and satisfaction to more objectively measure this construct.

To conclude, CGM provides detailed, objective data about glucose concentrations and trends and the use of this technology is feasible, even for young children with T1DM. Whereas

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more traditional measure of glycemic levels, such as SMBG provides data at discrete time points which may be predisposed to extreme values (e.g., pre-meal glucose or when hypo- or hyperglycemia is suspected), CGM data provide an unbiased sample of glucose values. Moreover, CGM is the only device available that can directly measure glycemic variability and the percent of time participants are at specific glycemic concentrations. These types of measurements can be particularly useful for behavioral researchers examining associations between patients' psychosocial functioning, self-care behaviors, and their glycemic control. These data may also become the best way to assess for glucose variability, which evidence suggests, should be a target for future behavioral interventions (4,5,6). Overall, CGM provides a technologically advanced method of obtaining data that allows for a richer and more detailed examination of glucose trends and correlates in children with T1DM.

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References

(1). American Diabetes Association. Standards of medical care for patients with diabetes mellitus. Diabetes Care. 2009; 32(S1):S13–61. [PubMed: 19118286]

(2). The Diabetes Control and Complications Trial. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The diabetes control and complications trial research group. N Engl J Med. 1993; 329:977–986. [PubMed: 8366922]

(3). The Diabetes Control and Complications Trial. Effect of intensive diabetes treatment on the development and progression of long-term complications in adolescents with insulin-dependent diabetes mellitus: Diabetes control and complications trial. Diabetes control and complications trial research group. J Pediatr. 1994; 125:177–188. [PubMed: 8040759]

(4). Cox DJ, Gonder-Frederick L, Ritterband L, Clarke W, Kovatchev BP. Prediction of severe hypoglycemia. Diabetes Care. 2007; 30:1370–1373. [PubMed: 17363757]

(5). Hirsch IB, Brownlee M. The effect of glucose variability on the risk of microvascular complications in type 1 diabetes. Diabetes Care. 2007; 30:186–187. [PubMed: 17192365]

(6). Hirsch IB. Glycemic variability: it's not just about A1C anymore! Diabetes Technol Ther. 2005; 7:780–783. [PubMed: 16241882]

(7). DiMeglio LA, Pottorff TN, Boyd SR, France L, Fineberg N, Eugster EA. A randomized, controlled study of insulin pump therapy in diabetic preschoolers. J Pediatr. 2004; 145:380–384. [PubMed: 15343195]

(8). Patton SR, Dolan LM, Powers SW. Mealtime interactions relate to dietary adherence and glycemic control in young children with type 1 diabetes. Diabetes Care. 2006; 29:1002–1006. [PubMed: 16644628]

(9). Buckingham B, Beck RW, Tamborlane WV, Xing D, Kollman C, Fiallo-Scharer R, et al. Continuous glucose monitoring in children with type 1 diabetes. J Pediatr. 2007; 151:388–393e2. [PubMed: 17889075]

(10). Weinzimer S, Xing D, Tansey M, Fiallo-Scharer R, Mauras N, Wysocki T, et al. Freestyle navigator continuous glucose monitoring system use in children with type 1 diabetes using glargine-based multiple daily dose regimens: Results of a pilot trial diabetes research in children network study group. Diabetes Care. 2008; 31:525–527. [PubMed: 18096811]

(11). Wilson DM, Beck RW, Tamborlane WV, Dontchev MJ, Kollman C, Chase P, et al. The accuracy of the freestyle navigator continuous glucose monitoring system in children with type 1 diabetes. Diabetes Care. 2007; 30:59–64. [PubMed: 17192334]

(12). Gandrud LM, Xing D, Kollman C, Block JM, Kunselman B, Wilson DM, et al. The medtronic minimed gold continuous glucose monitoring system: An effective means to discover hypo- and

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hyperglycemia in children under 7 years of age. Diabetes Technol & Ther. 2007; 9:307–316. [PubMed: 17705686]

(13). Opipari-Arrigan L, Fredericks E, Burkhart N, Dale L, Hodge M, Kichler J, et al. Implementing insulin pump therapy with preschoolers with type 1 diabetes mellitus: A pilot investigation of medical and quality of life outcomes. Pediatr Diabetes. 2007; 8:377–383. [PubMed: 18036064]

(14). Hollingshead, AB. Four-factor Index of Social Status. Yale University; New Haven, CT: 1975. Unpublished manuscript

(15). Burdick JH, Chase P, Slover RH, Knievel K, Scrimgeour L, et al. Missed Insulin Meal Boluses and Elevated Hemoglobin A1c Levels in Children. Pediatrics. 2004; 113:221–224.

(16). McDonnell CM, Donath SM, Vidmar SI, Werther GA, Cameron FJ. A novel approach to continuous glucose analysis utilizing glycemic variation. Diabetes Technol & Ther. 2005; 7:253–263. [PubMed: 15857227]

(17). McDonnell CM, Werther GA, Northam EA, Cameron FJ, Donath SM. Hyperglycemia and externalizing behavior in children with type 1 diabetes. Diabetes Care. 2008; 30:2211–2215. [PubMed: 17563334]

(18). Kaufman FR, Gibson LC, Halvorson M, Carpenter S, Fisher LK, Pitukcheewanont P. A pilot study of the continuous glucose monitoring system: Clinical decisions and glycemic control after its use in pediatric type 1 diabetic subjects. Diabetes Care. 2001; 24:2030–2034. [PubMed: 11723078]

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Table 1

Mean glucose levels, variation, and time in range by participant

Age (yrs)/Gender	HbA1c (%)	Mean CGM	Mean SMBG	CONGA 1	CONGA 2	CONGA 4	MODD	Below Range	% of time (CGM) In Range	Above Range
5/M	8.6	268	256	67	97	113	94	0%	17%	83%
6/F	7.5	168	172	50	72	90	74	2%	64%	34%
6/F	8.9	202	213	64	96	123	77	1%	47%	52%
4/M	8.0	235	208	58	90	126	104	2%	25%	73%
6/F	8.7	186	196	46	66	84	68	2%	45%	53%
4/M	7.0	158	192	60	73	100	68	11%	57%	32%
6/F	7.8	212	222	55	85	101	88	0%	38%	62%
5/F	7.7	268	223	74	114	145	79	2%	15%	82%
3/M	8.0	282	270	62	95	107	116	0%	10%	90%
5/M	7.2	213	212	67	91	121	138	13%	28%	59%
6/F	7.4	171	165	52	75	94	72	5%	55%	40%
2/M	8.3	128	134	67	86	100	79	24%	52%	23%
6/M	6.8	182	184	48	69	98	90	9%	42%	50%
7/F	6.6	144	169	44	66	81	35	6%	74%	20%
3/M	7.5	173	166	62	99	126	65	5%	58%	38%
6/M	7.0	187	209	45	68	97	64	0%	54%	46%
6/M	7.5	185	186	56	87	105	93	4%	48%	48%
3/M	8.1	214	188	54	82	106	79	3%	37%	59%
6/F	7.8	181	162	63	82	102	66	7%	44%	49%
6/F	8.3	200	273	54	78	115	118	7%	35%	59%
5/M	9.1	197	179	58	84	107	65	2%	40%	59%
6/F	8.0	150	190	68	94	128	75	19%	51%	30%
4/M	8.9	188	145	53	84	102	108	0%	52%	48%
7/M	6.8	141	178	66	80	85	119	16%	58%	26%
5/F	7.1	169	154	50	69	90	86	3%	60%	37%
5/M	7.5	198	203	62	84	100	89	0%	50%	50%
5/F	7.4	179	177	57	71	79	68	2%	50%	48%
5/M	8.4	249	206	57	84	114	128	3%	26%	71%
5/F	7.5	187	205	69	90	111	119	5%	54%	42%

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Age (yrs)/Gender	HbA1c (%)	Mean CGM	Mean SMBG	CONGA 1	CONGA 2	CONGA 4	MODD	Below Range	% of time (CGM) In Range	Above Range
4/M	7.4	161	200	55	79	95	83	7%	51%	41%
6/F	7.8	208	218	70	97	123	108	9%	36%	55%

Note: Below range = < 80 mg/dl, In range = 80 – 180 mg/dl, Above range = > 180 mg/dl. CONGA1 = Continuous overall net glycemic action (1 hour). CONGA2 = 2 hours. CONGA4 = 4 hours. MODD = Mean daily differences.

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Table 2

Comparison of glucose variability in young children with T1DM and older children with T1DM.

Variability Statistic	Young children with T1DM[a]	Older children with T1DM[a] (16)
MODD	88 ± 23*	78 ± 27*
CONGA1	58 ± 8**	44 ± 8**
CONGA2	83 ± 11**	64 ± 14**
CONGA4	105 ± 15**	82 ± 24**

Note: MODD = mean observed daily difference; CONGA1 = continuous overall net glycemic action (1 hour), CONGA2 = 2 hours, CONGA4 = 4 hours.

[a] Values shown are *M* ± *SD*. Means in the same row with asterisks are significantly different at the following levels:

* $p = .057$.

** $p < .000$.