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Jessica C. Kichler
Medical College of Wisconsin

Astrida S. Kaugars
Marquette University, astrida.kaugars@marquette.edu

Kelly Maglio

Ramin Alemzadeh
Medical College of Wisconsin

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Exploratory Analysis of the Relationships Among Different Methods of Assessing Adherence and Glycemic Control in Youth with Type 1 Diabetes Mellitus

Jessica C. Kichler
Child and Adolescent Psychiatry and Behavioral Medicine, Children's Hospital of Wisconsin and the Medical College of Wisconsin;
Astrida S. Kaugars
Department of Psychology, Marquette University
Kelly Maglio
Nutrition Services, Children's Hospital of Wisconsin
Ramin Alemzadeh
Department of Endocrinology and Diabetes, Medical College of Wisconsin

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Although there is a general consensus for the definition of adherence as, "The extent to which a person's behavior (in terms of taking medications, following diets, or executing lifestyle changes) coincides with medical or health advice" (Haynes, 1979; pp. 1–2), there is disagreement over how to operationally define and measure this phenomenon (Johnson & Carlson, 2004). Researchers suggest that for acute illnesses, there is approximately a 30% failure rate in patients adhering to their medical regimens and that this is even higher (50% or more) for chronically ill patients (DiMatteo, 1994; Rapoff, 2010). How, when, where, and by whom these behaviors are assessed in research result in different ratings of degrees of medical adherence (Johnson & Carlson, 2004). Similar to others with chronic illnesses, youth with Type I Diabetes Mellitus (T1DM) have been shown to often have difficulties with adherence to their medical regimen with nonadherence ranging from 20% to 93% (Kovacs, Goldsteon, Obrosky, & Iyengar, 1992; Rapoff, 2010; Wysocki, Buckloh, Lochrie, & Anal, 2005).

Johnson (2008) suggested that measures that attempt to assess the construct of adherence should be continuous, dynamic, and capture specific regimen behaviors relevant to the disease population. The typical self-management regimens for individuals with T1DM include conventional management, multiple daily injections (MDI), or continuous subcutaneous insulin injection (CSII). Regardless of the T1DM regimen prescribed, all patients have to monitor their blood glucose (BG), calculate carbohydrate content of meals and snacks, administer exogenous insulin daily, and make positive lifestyle choices (e.g., regular exercise, stress management, and healthy food choices). When assessing diabetes regimen adherence, some measures provide global information about adherence (e.g., summary scores from interviews about adherence behaviors) whereas other measures provide information about specific adherence behaviors (e.g., blood glucose monitoring, food choices). Thus, both the multidimensional nature of diabetes management as well as the assessment of regimen adherence is important for researchers and clinicians to consider.

Recent work by Quittner, Modi, Lemanek, Ievers-Landis, and Rapoff (2008) attempted to explore the evidence base for adherence assessments that related to the individual's execution of the recommended medical regimen for pediatric patients within a wide variety of chronic disease cohorts, including T1DM. Quittner et al. (2008) outlined three different methods of assessing these types of adherence behaviors within a pediatric T1DM population: self-report measures/structured interviews, diary measures, and electronic monitoring. For the self-report/structured interview category, the Self-Care Adherence Interview (SCAI; Hanson et al., 1989) was approaching meeting well-established criteria, while the Self-Care Inventory (SCI: La Greca, Swales, Klemp, & Madigan, 1988) and the Diabetes Regimen Adherence Questionnaire (DRAQ; Bronlee-Duffeck et al., 1987) were considered well-established measures. For the diary measure category, the 24-hour Recall Interview (Johnson, Silverstein, Rosenbloom, Carter, & Cunningham, 1986) was considered to be well-established. Finally, for the electronic monitoring category, BG monitors have been labeled as the "new gold standard" for adherence measurement as they are thought to produce more "objective" data than other sources of information (Quittner et al., 2008).

Quittner et al. (2008) also provided recommendations for use of these adherence measures in future research. They suggested that all studies assessing adherence should utilize at least two methods of diabetes adherence to test the convergence of the adherence ratings within the context of demographic variables, such as race/ethnicity differences. Additionally, researchers who want to use different methods of assessing diabetes adherence (i.e., self-report/structured interviews and/or diary measures) could then use electronic monitor data to "correct" for self-reported data or utilize newer statistical modeling techniques, which allow data from different methods to all be entered and accounted for when predicting health outcomes.

Although diabetes regimen adherence has been measured using different methods (e.g., self-report measures/structured interviews, diary measures, and electronic monitoring), all of these adherence assessments have been shown to be related to glycemic control (Hood, Peterson, Rohan, & Drotar, 2009; Kichler, Opipari, & Foster, 2008). Results from a meta-analysis by Hood et al. (2009) demonstrated a relationship between adherence and glycemic control among adolescents with T1DM, whereby adherence ratings were inversely correlated with glycosylated hemoglobin (HbA1c), a measure of glycemic control. However, Hood et al. (2009) only selected one adherence measure from each study included in the meta-analysis to demonstrate the adherence-HbA1c association, even if the studies utilized more than one type of adherence measure. Therefore, this study did not compare the different measures of adherence or determine which methodology best predicted glycemic control. Lewin and colleagues (2009) examined the validity of a self-report measure of diabetes adherence (SCI) by comparing it with a structured interview (i.e., Diabetes Self-Management Profile; Harris et al., 2000) and data from an electronic monitoring measure [that is, blood glucose (BG) meter download data taken from the medical chart]. They found that all of the measures of adherence were related to glycemic control. However, the purpose of the Lewin et al. (2009) study was to validate the SCI and not to conduct a comparison of the three types of diabetes adherence assessment methods to determine which best predicted glycemic control. To date, there has been no comprehensive examination of different methods of assessing diabetes adherence to understand their shared and/or unique contribution to glycemic control.

While research related to global measures of adherence has shown patterns of associations among adherence and health outcomes, there is also strong evidence demonstrating the importance of focusing on specific adherence behaviors. Blood Glucose Monitoring (BGM) is one type of diabetes regimen adherence behavior in the diabetes regimen that has been repeatedly found to be a significant, if not a sole, determinant of glycemic control (Anderson, Ho, Brackett, Finkelstein, & Laffel, 1997; Hood, Butler, Volkening, Anderson, & Laffel, 2004; Levine et al., 2001; Lewin et al., 2009). However, researchers extracting this data have used different types of assessment methodologies (e.g., meter downloads listed in patients' medical charts, provider ratings, self-report questionnaires, and/or interviews). Regardless of these differences in methodology of obtaining BGM data, it is well-established in the literature that BGM adherence is a strong predictor of glycemic control and is often utilized as a proxy of more general overall adherence (Hood et al., 2009). Yet, BGM assessment is still fraught with concerns about reliability and validity (Guilfoyle, Crimmins, & Hood, 2011; Quittner et al., 2008). A better understanding of the assessment of BGM, both within the context of the relationship among the different types of BGM measurements as well as how this specific type of regimen adherence behavior relates to more global assessments of adherence, is warranted in the literature.

The present study focuses on exploring associations of both global and specific aspects of diabetes regimen adherence by examining four methods of assessment (i.e., self-report, diary measure, electronic monitoring, and provider rating). The assessment methods vary in terms of methodology (i.e., paper-and-pencil, interview, electronic monitoring), the time frame of the assessment taking place (i.e., previous 24 hours vs. 2 weeks), the individual providing the information (i.e., patient, parent, or provider rating), and the type of contact with the informant (i.e., in person, over the phone, or medical chart extraction). Therefore, while there is variability among the different methods, the goal of the study is to examine the similarities and differences across the various methods of assessing diabetes adherence. This study first hypothesizes that the four methods of assessing diabetes adherence (i.e., self-report, diary measure, electronic monitoring, and provider rating) will all be moderately related to one another, despite differences in obtaining the adherence data. A unique contribution of the present study is the comparison among global measures of adherence and information about adherence to specific diabetes regimen behaviors. While it is assumed that a global score represents an overall estimate of individual behaviors, additional empirical investigation of the actual associations is warranted. Second, this study hypothesizes that there will be significant relationships among the various BGM measurements, which are a specific type of adherence behavior for diabetes, and glycemic control. Finally, exploratory analyses will determine if one method of assessing diabetes adherence has a stronger relationship to glycemic control than the other methods of measuring diabetes adherence, even after demographic variables are taken into account.

Method

Participants

Seventy-six youth with T1DM between the ages of 12 and 17 years (Mean Age = 14.39 ± 1.52; 52.6% Female; 76.3% had a duration of diabetes > 2 years) who were receiving diabetes care at a Midwestern children's hospital and at least one parent/caregiver were recruited for the study. Participants with diagnosis of hypothyroidism maintaining normal thyroid function studies were included in the study. Participants who were on stable psychotropic medications (i.e., dose stable for at least 3 months) were included in the study. The participants were excluded if (a) they had a coexisting diagnosis of mental retardation, pervasive developmental disorder, celiac disease, adrenal insufficiency, substance dependence, eating disorder, or psychosis, or (b) they were not fluent in the English language. This study was approved by the Human Subjects Review Board.

The parents and youths were asked to give consent/assent and complete a demographic information sheet, study questionnaires (including measures of adherence to diabetes regimen), and interviews before or after their diabetes clinic visit. In addition, participants completed a 24-hour Recall Interview of their diabetes self-management. Two weeks of BG glucometer data were also collected and/or downloaded. As a part of their routine medical care, providers assessed adolescents' pubertal development (using the Tanner Scale) and rated adolescents' BG testing frequency based on their clinical impressions during their medical visit with the families. The providers did not have access to the glucometer downloads collected by the research personnel, but they had access to the glucometer and any BG logs that the family may have provided to them in clinic independent of the study. The clinic visit included a collection of HbA1c levels and height and weight measurements. This information was extracted from the medical chart for study purposes. Similar to the procedures used by Helgeson, Viccaro, Becker, Excobar, and Siminerio (2006), the participants were also asked to provide two additional 24-hour Recall Interviews at 6 and 12 weeks following enrollment via phone with the same dietitian that completed their baseline assessment. Each participant received a $20 stipend for their participation.

The present study is part of a larger study that recruited adolescents with T1DM or Type 2 Diabetes Mellitus (T2DM). Families were recruited through an opt-in postcard method, where letters introducing the study were mailed to the potential participants' homes. They were asked to mail back a postcard indicating if they did or did not want to be contacted for further information about the study. Of the families who were recruited via postcard methods, 100 patients expressed an interest in participating and 18 declined participation in the study. Seven of these 100 patients who expressed an interest in the study did not participate due to eligibility or scheduling conflicts. Of the 93 patients who did participate in the study, 17 were excluded for the purposes of the present study due to age or type of diabetes diagnosis. The present analyses included 76 participants.

The majority (59.8%) of the participants had late pubertal ratings (Tanner Stages 4 and 5), and the mean BMI Standard Deviation Score (BMI SDS) for the sample was 0.65 (*SD* = 0.78) . 85.5% of this sample was Caucasian (*n* = 65), and 14.5% endorsed non-Caucasian backgrounds (*n* = 11; 4 African American, 5 Hispanic, 1 Native American, and 1 biracial African American/Caucasian youth). The majority of the parents were married (78.7%), an additional 8.0% reported that they were either separated or divorced, and 13.3% reported other relationship status (e.g., never married, remarried, or other).

Measures

Demographic information form

Caregivers provided information about demographic characteristics, such as youths' birth date, height, weight, type of diabetes, ethnicity, duration of diabetes, parent marital status, and any additional medical and/or psychiatric diagnoses for the immediate family. Previous research has found relationships between these demographic variables and adherence and glycemic control (Delamater et al., 1999; Edmonds-Myles, Tamborlane, & Gray, 2010).

Self-Care Inventory (SCI; **La Greca et al., 1988**; **Greco et al., 1990**)

This self-report questionnaire measures adherence to the diabetes regimen over the past month across a series of self-care activities (e.g., BG testing and clinic visits). Items are rated on a 5-point Likert scale, where higher scores indicate better adherence to diabetes treatment recommendations. Adequate internal consistency (α = .76–0.87) and strong test–retest reliability have been reported (La Greca et al., 1988; Lewin et al., 2009). La Greca (2004) recommends that all 14 items be administered, but that 7 items be omitted when calculating the overall adherence score to generate an adjusted total score, which is better linked with glycemic control. The adjusted total score is calculated by taking the mean of the 7 total items answered as there is an option of "not applicable" in the questionnaire. In addition, La Greca (2004) empirically validated four conceptual factors that can be calculated from obtaining the mean score of the items: BG regulation, insulin and food regulation, exercise, and emergency precautions. For the present study, analyses included the adjusted total score, factor scores, and item 1 (i.e., In the past month, how well have you followed recommendations for glucose testing). The internal consistency for the present sample was good for the all items in the total score (α = .84) and acceptable for the selected items in the adjusted total score (α = .77). The revised version of the SCI was not available when this study was first developed; therefore, this study utilized the original SCI measure.

24-hour Recall Interview (**Johnson et al., 1986**)

The 24-hour Recall Interview is an assessment of 13 different diabetes-related adherence behaviors, including insulin injections, dietary intake, exercise, and BG and urine ketone monitoring on multiple occasions by multiple informants, where higher scores indicate poorer adherence and scores closer to zero represent relative adherence. In addition, the 13 adherence behaviors can be grouped into five factors that have been empirically derived using factor analyses: exercise, injection, diet type, testing/eating frequency, and diet amount (Johnson et al., 1986). This recall is initiated by asking the adolescent to recall the previous day's events in a temporal sequence from the time he or she woke up to the time he or she went to bed on the previous day. The interviewers record all diabetes-related activities and prompt for further information, if omitted. The parent–child concordance and reliability and validity of the 24-hour Recall Interview have been previously determined to be acceptable, especially among children over 10 years of age (Freund, Johnson, Silverstein, & Thomas, 1991; Reynolds, Johnson, & Silverstein, 1990). The protocol for the 24-hour Recall Interviews was modeled after Helgeson et al. (2006) and occurred at three time points: baseline (Time A), 6 (Time B), and 12 weeks (Time C). Two of these assessments were for weekdays and one for a weekend day. These three interviews were averaged together to determine 13 adherence variables and the five factors.

Blood glucose (BG) meter data collection/downloading

All participants were asked to bring their glucometers and BG logbooks to the research appointment. Glucometers contain a memory chip that holds BG data for at least the previous two weeks. These data include the time and date of the BG checks and levels. This information was collected or downloaded on the day of their appointment directly by research personnel and was not shared with medical personnel as a part of their clinic visit. Previous research procedures have examined two weeks worth of glucose testing frequency rates (Miller & Drotar, 2003, 2007) as a measure of adherence to the diabetes regimen recommendations. A daily BG testing frequency average was determined for this study for the previous two weeks (i.e., the 14-day meter BGM frequency average).

Statistical Analyses

Table 1 outlines the four different methods of assessing diabetes adherence (i.e., self-report, diary measure, electronic monitoring, and provider rating) and the specific BMG scores that were utilized in the analyses. Bivariate correlations were conducted to determine associations among demographic variables (e.g., age at participation, length of time since diagnosis, BMI SDS scores, and pubertal ratings) and the adherence measures (e.g., Adjusted SCI score, Factors 1–5 of the 24-hour Recall Interview, the 14-day meter BGM frequency average, and the provider rating of BGM from the medical chart). *T* tests were conducted to determine any mean differences in the adherence measures for the categorical demographic variables (i.e., Caucasian vs. non-Caucasian status, parent marital status, and adolescent gender). To better understand the relationships among the different BGM adherence measures, additional correlations among the six different types of BGM measurements were conducted (e.g., SCI Factor 1, SCI Item 1, Injection Factor 4 on 24-hour Recall Interview, Item 13 on the 24-hour Recall Interview, 14-day BGM meter average, and the provider rating of BGM from the medical chart). Although all participants were asked to bring their BG meter for the study, 5 of the participants did not bring BG numbers at all, and 16 of the participants did not bring a full 14 days worth of BG numbers (i.e., 10 participants brought 13 days worth and 6 participants brought 5–10 days worth of BG numbers). Therefore, the 14-day BGM meter averages were based on the mean number of blood glucose checks per day available to the researchers. The 14-day BGM meter average variable is based on 71 of the 76 participants as that missing meter data could not be extrapolated. Correlations were then conducted among the adherence measures. Exploratory analyses were conducted using stepwise regression methodology to determine the best set of adherence predictors of HbA1c while controlling for the relevant demographic variables. The adherence measurements (e.g., Adjusted SCI score, Factors 1–5 of the 24-hour Recall Interview, the 14-day meter BGM frequency average, and the provider rating of BGM from the medical chart) were entered in the regression. Cohen's indexes for correlation coefficients (small = .10, medium = .30, large = .50) and for multiple regressions (small = .02, medium = .15, large = .35) were used to determine the effect sizes for all analyses conducted (Cohen, 1992).

Table 1. *Summary of Four Methods of Assessing Adherence*

	Self report	Diary measure	Electronic monitoring	Provider rating
Measures	Self Care Inventory	24-hour Recall Interview	Glucometer	Medical Chart
Definition	Adjusted total adherence score	1. Exercise 2. Injection 3. Diet type 4. Testing/eating frequency 5. Diet amount	14-day average of BGM frequency per day	Provider rating of average BGM frequency per day

Results

Descriptive Statistics

Of the demographic variables, BMI SDS and Tanner stages were significantly related to Adjusted SCI, while BMI SDS was also related to the 24-hour Recall Factor 4 (testing/eating frequency) and Factor 5 (diet amount). *T* tests were then conducted to determine any mean differences in the adherence measures for categorical demographic variables (e.g., Caucasian vs. non-Caucasian status, parent marital status, and adolescent gender). Caucasian youth had significantly higher adherence scores than non-Caucasian youth for the 24-hour Recall Factor 4 (testing/eating frequency), $t = -2.62$, $p < .05$, as well as the glucometer and provider ratings from the medical chart of BGM ($t = 2.50$, $p < .05$ and $t = 2.15$, $p < .05$, respectively). There was one difference found for females versus males on the 24-hour Recall Factor 5 (diet amount), where females had higher adherence scores, $t = 4.46$, $p < .01$. Given the multiple significant relationships between some of the demographic variables (i.e., BMI SDS and Caucasian vs. non-Caucasian status) and the adherence measures, these two demographic variables were subsequently utilized in the regression analyses as covariates.

Relationships Among Global Adherence Measures and BGM

Among the four methods of assessing diabetes adherence (i.e., self-report, diary measure, electronic monitoring, and provider rating), the Adjusted SCI was significantly related to 24-hour Recall Factors 2 (injection administration), 4 (testing/eating frequency), and 5 (diet amount) as well as both the meter BGM frequency average and the provider rating of BGM from the medical chart. The meter BGM values were also significantly correlated with the 24-hour Recall Factors 1 (exercise) and 4 (testing/eating frequency) as well as the provider rating of BGM frequency from the medical chart. The provider rating of BGM from the medical chart was also significantly correlated with the 24-hour Recall Factor 4 (testing/eating frequency). Therefore, scores from the adherence measures are interrelated at medium to large (*r*s = .24–.48) effect size levels (Cohen, 1992) (see Table 2).

Table 2. *Correlations of Global Adherence Measures and BGM*

Variable SCI	Adjusted global score	24-hour Recall Interview Factor 1 (Exercise)	24-hour Recall Interview Factor 2 (Injection)	24-hour Recall Interview Factor 3 (Diet type)	24-hour Recall Interview Factor 4 (Frequency)	24-hour Recall Interview Factor 5 (Diet amount)	Meter mean BGM checks 14-day
24-hour Factor 1	0.07	1.0					
24-hour Factor 2	−.31**	.24*	1.0				
24-hour Factor 3	.07	.08	.11	1.0			
24-hour Factor 4	−.42**	.09	.27*	−.07	1.0		
24-hour Factor 5	.27*	−.04	−.27*	.04	−.40**	1.0	
Meter 14-day BGM	.24*	−.29*	−.19	.04	−.27*	.15	1.0
Provider rated BGM	.37**	−.07	−.18	.03	−.30**	.20	.48**

Note. SCI = Self Care Inventory; BGM = Blood Glucose Monitoring.
**p* _ .05. ***p* < .01.

Relationships Among Blood Glucose Monitoring (BGM) Variables and HbA1c

Correlations were conducted among the BGM variables and glycemic control (HbA1c). There were statistically significant correlations, representing medium to large (*r*s = .27–.75) effect sizes (Cohen, 1992) among the six BGM variables [that is, SCI Factor 1 (BG regulation), SCI Item 1 (Glucose testing), 24-hour Recall Interview Factor 4 (testing/eating frequency), 24-hour Recall Interview Item 13 (glucose testing frequency), the 14-day meter BGM frequency average, and the provider rating of BGM from the medical chart in the expected direction (see Table 3). Table 3 also includes the significant relationships found among almost all of the BGM variables and HbA1c.

Table 3. *Correlations Among BGM Measures and Glycemic Control (HbA1c)*

Measure	SCI Factor 1	SCI Item 1	24-hour Factor 4	24-hour Item 13	BGM meter 14-day	BGM provider rating
SCI	.75**_					
Item 1		1.0				
24-hour Recall	-.07	-.27*				
Factor 4			1.0			
24-hour Recall	-.29*	-.40**	.29*			
Item 13				1.0		
BGM Meter	12	.13	-.19	-.39**		
14 day					1.0	
BGM	18	.34_	-.18	-.45_	.48**	
Provider Rating						1.0
HbA1c	_.32_	-.39_	.35_	36_	-.31_	-.22

Note. SCI = Self Care Inventory; BGM = Blood Glucose Monitoring.
*p < .05. **p < .01.

Exploratory Stepwise Regressions for Glycemic Control

An exploratory stepwise multivariate regression analysis was conducted to determine which adherence assessments accounted for significant amounts of variance in predicting glycemic control, as measured by HbA1c. The covariates that were initially identified as being related to the independent variables (i.e., BMI SDS and Caucasian vs. non-Caucasian status) were entered stepwise in the first step. Then, the variables derived from the four methods of adherence assessments were entered in the second step (i.e., Adjusted SCI score, Factors 1–5 of the 24-hour Recall Interview, the 14-day meter BGM frequency average, and the provider rating of BGM from the medical chart). In the stepwise regression, step 1 identified Caucasian versus non-Caucasian status as the most robust predictor of HbA1c, accounting for 30.1% of the variance ($\beta = 0.44$, $p < .01$). Then, in step 2 the Adjusted SCI emerged as the most robust predictor, with a medium ($f^2 = .21$) effect size (Cohen, 1992), accounting for an additional 17.3% of the variance ($\beta = -0.43$, $p < .01$). These findings suggest that the Adjusted SCI was the strongest predictor of HbA1c after controlling for Caucasian versus non-Caucasian status (see Table 4).

Table 4. *Stepwise Regression for Adherence Assessments and HbA1c*

			HbA1c		
	R	R^2	SR^2	ΔR^2 (F)	β
Step 1 (Demographics)					
Caucasian vs. Non-Caucasian	.55	.30	.30	31.89	0.55**
BMI SDS					0.12
Step 2 (Adherence Measures)					
Adjusted SCI	.69	.47	.17	24.03	-0.43**
24-hour Recall Interview Factor 1					-0.04
24-hour Recall Interview Factor 2					0.14
24-hour Recall Interview Factor 3					0.03
24-hour Recall Interview Factor 4					0.12
24-hour Recall Interview Factor 5					-0.63
BGM Meter 14-day					-0.11
BGM Provider Rating					-0.02
Final Model [Step 1 (Demographics) and Step 2 (Adherence Measures)]					

Caucasian vs. Non-Caucasian					0.44**
Adjusted SCI					-0.43**

* p < .05. ** p < .01.

Discussion

The present study examined four methods of assessing diabetes adherence (i.e., self-report, diary measure, electronic monitoring, and provider report) within a population of youth with T1DM. The study hypothesized that scores from the adherence methods would all be related to one another, despite differences in how, when, from whom, and where the adherence information was obtained. The adherence assessments appeared to be interrelated, and the most robust associations were among the SCI and the other adherence assessments. The analyses also examined associations between more general assessments of adherence and behavior-specific assessments (i.e., BGM). The results from this study support the findings of Lewin et al. (2009), who also used multiple methods of assessing diabetes adherence (i.e., SCI, 24-hour Recall Interview and BGM frequencies taken directly from glucometers), and found that the SCI was related to other assessments of diabetes adherence and glycemic control.

The second study hypotheses predicted that there would be significant relationships among the various measures of BGM and glycemic control. The results of this study suggest that the various measures of BGM appear to be interrelated, but the most robust associations were among the other BGM variables and two glucose testing frequency items on the SCI and 24-hour Recall. In addition, there were similarly strong relationships between glycemic control and all of the BGM measures, except for provider rating of BGM from the medical chart. Therefore, future studies that do include a provider rating of BGM should also include another method of obtaining BGM data, such as a self-report, diary interview, or electronic monitoring download.

The exploratory stepwise regression analysis in this study determined that the adjusted score from the SCI self-report questionnaire had a stronger relationship to HbA1c than the other adherence assessments, even after controlling for the relevant demographic variables. The SCI is a robust, easy-to-use, and cost-effective measure of adherence that demonstrates convergent and predictive validity. One previous criticism of the SCI is that it is not the most up-to-date with the current diabetes regimens. The SCI has been updated and the SCI-R is now available for use. Weinger, Welch, Butler, and La Greca (2005) outlined that the SCI-R has 15 items at a 6th grade reading level. The specific changes to the SCI into the SCI-R are as follows: two items about eating meals and snacks on time were combined, the exercise strenuously item was omitted but the exercise regularly item remained, the wording about BG was changed from “testing blood glucose” to “check blood glucose with monitor,” as well as “recording ketones” was changed to “check ketones when blood glucose level is high.” In addition, three items were added around “keeping food records,” “reading food labels,” and “treating a low blood glucose.” Then, the “not applicable” option was removed from all the items, except for the ones about ketones, insulin, and pills because these do not apply to everyone. Therefore, the content of the SCI-R remains similar to the SCI, despite the revision to the wording of some items and the updates with the current diabetes practice. While it was not used in the present study, the revised SCI-R should be used in future studies.

Hood et al. (2009) suggested in a meta-analysis that ethnicity did not impact the adherence-glycemic control relationship. The results of the present study are consistent with those findings in that there remained an adherence-glycemic control relationship for the self-report adherence questionnaire (Adjusted SCI score) and glycemic control, even after Caucasian versus non-Caucasian status was taken into account. However, the findings from the present study suggest that Caucasian versus non-Caucasian status does have a significant impact on explaining glycemic control. Caucasian versus non-Caucasian status emerged as the most robust demographic predictor of glycemic control and it explained approximately 30% of the amount of variance.

Therefore, future studies should examine the adherence-glycemic control relationship within the context of ethnicity as Quittner et al. (2008) suggested.

In addition to recommendations of examining adherence methodology within the context of race/ethnicity, Quittner et al. (2008) also suggested that researchers who use different methods of assessing diabetes adherence (i.e., self-report/structured interviews and/or diary measures) could use electronic monitor data to "correct" for self-reported data when predicting health outcomes. The results of the present study suggest that the most robust predictor of the glycemic control from an adherence standpoint was not the electronic monitor data, but the self-report method. Although electronic monitoring has been shown to converge with other well-established measures of general adherence, using electronic monitor data to correct for self-reported data may not be warranted. Future research should not rely solely on electronic monitoring data to predict health outcomes or be a proxy for more general adherence methods but should also include a well-established self-report measure, such as the SCI.

There are several limitations to this study. In cross-sectional studies such as these, causal inferences cannot be made for the relationships among variables. In the present study, only 14.5% of the participants were of non-Caucasian background. Therefore, there were not enough participants in different racial and ethnic groups to separate into individual categories for data analyses and subsequent interpretation. In addition, socioeconomic status was not assessed or analyzed as a potential contributing demographic variable (Delamater et al., 1999). Finally, although this study utilized "well-established" methods of assessing adherence, there were many measurement differences (e.g., how, when, from whom, and where the adherence information was obtained). Specifically, there were differences in the timeframe of the adherence behaviors that were assessed (e.g., 2 weeks, 1 month, and 3 months). Given that these multiple differences were embedded in the different measures, they were not separated into individual categories for data analyses. Future research may want to assess these four methods of diabetes adherence while keeping the timeframe of adherence behaviors being measured constant to see if that is a determining factor for predicting glycemic control.

The present study examined four methods of assessing adherence (i.e., self-report, recall/diary, electronic monitoring, and provider rating of BGM assessments) in youth with T1DM. Results found that despite methodological differences in the adherence measures, they were related to one another and to glycemic control. However, the self-report form appeared to have the most robust relationships among the adherence measures and emerged as the strongest predictor of glycemic control. Future studies may want to examine these four methods of assessing adherence longitudinally, while controlling for the timeframe of assessing these adherence behaviors. As mentioned earlier, the method of assessing both general adherence a behavior specific adherence (e.g., BGM) has to be clearly documented in future studies for transparency. Finally, future studies need to explore the role of other demographic variables in predicting glycemic control, such as socioeconomic differences, within the context of these various methods of assessing adherence in order to develop appropriate and relevant interventions.

Footnotes

1 Body Mass Index Standard Deviation Scores (BMI SDS) are calculated using the following equation: $(BMI - \langle BMI \rangle)/SD$, where BMI is weight/height^2, and $\langle BMI \rangle$ and SD are the mean BMI and standard deviation for a specific age (Nigrin & Kohane, 1999).

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