Published in final edited form as:

J Dev Behav Pediatr. 2013 April ; 34(3): 186–196. doi:10.1097/DBP.0b013e318287cb48.

Patterns of Self-Management in Pediatric Type 1 Diabetes Predict Level of Glycemic Control Two Years Later

Jennifer M. Rohan, M.A.^{1,2}, Jennifer Shroff Pendley, Ph.D.³, Alan Delamater, Ph.D.⁴,
Lawrence Dolan, M.D.⁵, Grafton Reeves, M.D.⁶, and Dennis Drotar, Ph.D.^{1,2}

¹Department of Pediatrics, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA, 45229

²Department of Psychology, University of Cincinnati, Cincinnati, OH, USA, 45221

³Division of Behavioral Health, Alfred I. duPont Hospital for Children, Wilmington, DE, USA, 19803

⁴Department of Pediatrics, University of Miami, Miami, FL, USA, 33136

⁵Division of Endocrinology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA, 45229

⁶Division of Pediatric Endocrinology, Alfred I. duPont Hospital for Children, Wilmington, DE, USA, 19803

Abstract

Objective—To determine if three distinct self-management patterns (i.e., maladaptive, moderate/mixed, and adaptive) observed at baseline, one, and two years in a sample of youth with type 1 diabetes and their caregivers predicted mean differences in adolescent's subsequent glycemic control.

Methods—This study is a descriptive, multisite, prospective study that examined a sample of youth diagnosed with type 1 diabetes (ages 9–11 years at baseline). Youth and their maternal and paternal caregivers provided information about the youth's self-management patterns at baseline, one, and two years using the Diabetes Self-Management Profile (DSMP) structured interview. Glycemic control (Hemoglobin A1c: HbA1c) was examined at baseline, six, 12, 18, and 24 months.

Results—Three distinct self-management patterns were observed at one and two years that were conceptually consistent with previously reported baseline self-management patterns. Youth identified by their maternal caregivers as having adaptive self-management patterns at baseline had better glycemic control across two years compared to those in the maladaptive and mixed self-management groups. Similarly, maternal reports suggested that youth with less adaptive self-management patterns generally had worse glycemic control over time as well as HbA1c values above the American Diabetes Association recommendations. Youth and paternal caregiver reports yielded more variable findings.

Conclusions—Findings underscore the stability of self-management patterns in pediatric type 1 diabetes and the need for preventive interventions that are tailored to specific patterns of self-management associated with risk for problematic glycemic control.

Keywords

PEDIATRICS; TYPE 1 DIABETES; SELF-MANAGEMENT; GLYCEMIC CONTROL; CLUSTER ANALYSIS

Managing the various treatment regimens for pediatric type 1 diabetes can be very difficult for many youth and their families, particularly during the transition from childhood to adolescence when self-management and glycemic control typically decline [1–6]. Self-management for type 1 diabetes is multifaceted and involves multiple domains of care, including but not limited to, complex insulin adjustments, dietary management, and treatment adherence (i.e., frequent blood sugar monitoring). Individual variation in an adolescents' pattern of self-management may predict clinically relevant outcomes, especially glycemic control [7]. Consequently, measurement of individual differences in patterns of self-management can help to target specific areas to improve glycemic control and reduce future health complications [8–10].

Previous studies have shown that maladaptive patterns of diabetes self-management at a single point in time were associated with less adequate glycemic control among adolescents during the same time period [11, 12]. A number of previous research studies have been limited by the following methodological problems: 1) cross-sectional study designs, which did not allow prediction of glycemic control; 2) absence of a comprehensive assessment of family reporters (e.g., youth, maternal, and paternal) that provided reports of the adolescents' self-management patterns; and, 3) no assessment of clinical relevance of glycemic control (e.g., whether glycemic control was within recommended clinical targets). To address these needs, this study examined if three distinct self-management patterns (i.e., maladaptive, moderate/mixed, and adaptive) identified in a pediatric sample of early adolescents with type 1 diabetes (see Rohan et al. [12]) predicted glycemic control six, 12, 18, and 24 months later.

Sustaining adequate glycemic control over time is the primary goal of clinical management in pediatric type 1 diabetes [13]. However, many adolescents with Type 1 Diabetes have difficulty maintaining levels of glycemic control that are within the American Diabetes Association (ADA) recommendations [13] for children and adolescents (i.e., Hemoglobin A1c (HbA1c) < 8% ages 6–12 years and < 7.5% ages 13–19 years) [1, 10]. There is substantial evidence that diabetes self-management patterns influences glycemic control: those with poor diabetes self-management skills across one or more domains of diabetes care often have worse glycemic control compared to those with higher, more adaptive self-management patterns who follow healthcare provider recommendations for exercise, diet, blood sugar testing and management, and insulin administration [5, 7, 11, 12, 14]. Thus, we hypothesized that across reporters the baseline maladaptive self-management group [12] would have worse glycemic control across time compared to the baseline moderate/mixed and adaptive self-management groups [12]. We also hypothesized that those in the maladaptive and moderate/mixed self-management groups at baseline, would have clinically significant HbA1c values that were above the age-based ADA recommendations six to 24 months later [12].

A second contribution of our study was to document stability and change in clusters of self-management and prediction of glycemic control over time. This is important because the efficacy of self-management and glycemic control have been shown to decline among adolescents with type 1 diabetes [1–6] but prospective studies have not described stability and change in patterns of self-management over time. To address this issue, we examined if: 1) the self-management patterns (all reporters) that were observed at baseline (see Rohan et

al. [12]) were consistent with those self-management patterns observed at one and two years and then examined how these changes in self-management patterns predicted glycemic control at later points in time; 2) whether early adolescents' self-management patterns remained stable over time or became more/less adaptive; and, 3) if self-management patterns observed at one and two years post-baseline predicted mean differences in subsequent HbA1c over time. We hypothesized that: 1) there would be three distinct self-management groups at one and two years post-baseline (i.e., maladaptive, moderate/mixed, and adaptive) that were similar to those obtained at baseline; and, 2) based on the above rationale that those with maladaptive self-management patterns at one and two years post-baseline would have worse glycemic control over time.

Methods

Participants and Procedure

Participants were children and adolescents (baseline: $N=239$, one year: $N=225$, two year: $N=225$) with type 1 diabetes and their caregivers who were followed at pediatric diabetes clinics at three university affiliated medical centers in the United States. Demographic and medical characteristics of the baseline, one year, and two year samples are provided in Table 1. Ethnicity was largely representative of each clinic's sample. Institutional Review Boards at each site approved the study. Data were collected as part of an ongoing, three-year longitudinal study that examined trajectories of adherence during the developmental transition from pre-adolescence to adolescence. Baseline self-management patterns have been published [12].

Primary eligibility criteria included a diagnosis of type 1 diabetes for at least one year, aged 9–11 years at recruitment, absence of potential secondary causes of type 1 diabetes (e.g., glucocorticoid treatment, cystic fibrosis), English speaking, no known plans to move out of the area within the next three years, no current involvement in foster care, absence of severe psychiatric disorders or comorbid chronic conditions (e.g., renal disease) that required burdensome ongoing treatment regimens, and no diagnosis of mental retardation.

Eligible participants were identified and contacted by clinic personnel to ask about their interest in the study and then were approached by research staff during a regularly scheduled outpatient clinic visit. Of the 361 eligible participants who were approached, 240 (66.5%) consented and participated. Reasons for not participating included being too busy ($n=54$), no transportation ($n=3$), and other (e.g., not interested, did not return recruitment calls, did not attend clinic regularly, etc.; $n=64$). Signed informed consent was obtained from a parent or legal guardian, written assent from children 11 years and older and verbal assent from children less than 11 years. After enrollment, one child was diagnosed with monogenic diabetes of the young (MODY) [15] and no longer treated with insulin and hence was removed from the study and analysis.

Overall attrition from baseline to two years was 3.3% ($n=8$). Reasons for discontinuing participation included: child and/or family no longer interested in research ($n=2$), family moving out of the area ($n=1$), patient changed endocrinologists and the doctor was not affiliated with the hospital ($n=1$), family was too overwhelmed to participate in research ($n=1$), and family would not schedule research visit and were dropped by study personnel ($n=3$). Missing data due to non-completion of visits included 13 at one year and 14 at two years. There were no significant differences (all $p > .05$) between those who participated in the one and two year follow-ups and those who did not complete the one and/or two year study visit ($N=18$) with respect to baseline disease duration, age, race, income, household composition (one versus two-parent), child's gender, insulin delivery method at baseline, 12, and 24 months, or HbA1c obtained at baseline, six, and 18 months.

Measures

The Diabetes Self-Management Profile (DSMP) is a 25-item structured interview administered independently to children and their caregivers to assess diabetes-related management behaviors during the previous 3 months [16]. Open-ended questions addressed the following domains: exercise, hypoglycemia management, diet, blood glucose monitoring, and insulin administration. The DSMP included both dichotomous items (yes, no) and three- to five-point likert scale items coded based on child and caregiver response to open-ended questions. A total self-management score was calculated by summing all items, and subscale scores were obtained by summing items for each appropriate scale. Higher scores reflected better self-management behaviors. The DSMP total score has demonstrated good internal consistency ($r = .76$), moderate agreement between parent and youth reporters ($r = .61$), and strong inter-rater agreement ($r = .94$) [16]. This measure also has demonstrated good predictive validity between parent and child reported self-management behaviors and glycemic control [16]. Internal consistency for the present sample at baseline was .60 for the youth DSMP, .66 for the maternal DSMP, and .64 for the paternal DSMP.

Glycated hemoglobin (HbA1c) provided an estimate of glycemic control over the previous two to three months. Blood samples were obtained by a finger stick during the study visit (baseline, 12, and 24 months) or at a clinic visit (six and 18 months) and samples from each study site were shipped to one central laboratory for standardization purposes. Samples were analyzed using the TOSOH-G7 method (reference range 4.0–6.0%).

Data Analytic Strategy

Identification of Self-Management Clusters from Baseline to Two Years:

Cluster Analytic Procedures—The same statistical method that was used to identify the baseline self-management clusters in the original report [12] (i.e., Two-Step Cluster Analysis) was used to identify self-management patterns at both one and two years. The purpose of cluster analysis is to identify mutually exclusive groups/clusters of individuals who have similar scores on one or multiple subscales [11, 12, 17]. Cluster analysis was used to generate the type of self-management patterns (e.g., maladaptive, mixed, or adaptive self-management) based on how youth, maternal, and paternal caregivers separately perceived the youth's diabetes self-management across five diabetes management domains (e.g., exercise, hypoglycemia management, diet, blood glucose monitoring, and insulin administration). It was possible for the youth to be classified as being in different self-management groups based on self-, maternal, or paternal-report.

Current analyses followed recommendations for a rigorous two-step process to identify robust and clinically relevant cluster patterns [17–19] using SPSS 17.0 and 20.0: For two-step cluster analysis, each individual's subscale raw scores are transformed to z scores prior to the analysis to standardize results across participants and ensure that measurement error is minimized when determining group membership. The two-step cluster analysis first identifies “pre-clusters” and then treats these “pre-clusters” as single cases in a hierarchical cluster analysis [18]. Two-step cluster analysis uses the cluster distances approach (i.e., maximizing between groups differences and minimizing within group differences) to generate self-management group profiles. These profiles are used to generate a single descriptive variable (e.g., maladaptive, mixed, or adaptive self-management) that describes the type of self-management at a given timepoint based on individual responses across one or more domains [11, 17, 18]. Finally, model fit statistics were used to identify the “best statistical model,” which was the model with the lowest Bayesian Information Criterion (BIC) [18].

Definition of Self-Management Group Membership—Two-step cluster analysis identified three mutually exclusive self-management groups (maladaptive, moderate/mixed, and adaptive) for youth, maternal, and paternal reporters at baseline, one, and two years. The general patterns for the one and two year self-management clusters were similar to those reported at baseline [12]. “Maladaptive self-management” was defined as having deficits in most/all areas of diabetes management as measured by the DSMP. Adolescents in this group (self-report and parental report) had problems/difficulties with the following self-management behaviors: obtaining appropriate amounts of exercise and adjusting insulin based on exercise; managing and treating hypoglycemia and/or hyperglycemia; carbohydrate counting; eating frequent amounts of sweets and fatty foods; eating more/less than what was bolused; completing the prescribed number of blood glucose checks; testing for ketones; and difficulty with insulin administration. Adolescents in this group consistently had lower overall self-management scores as well as lower scores across all five domains compared to the mixed and adaptive self-management groups.

“Moderate adaptive/mixed self-management” was defined as having difficulty in managing one or more areas of diabetes management, but not necessarily difficulty in all areas of diabetes management. These individuals were likely to have variable patterns of self-management and reported some areas that they were doing relatively well, but reported difficulty in other areas that were not being managed quite as well. Finally, “adaptive self-management” was defined as having few or no deficits in diabetes management (i.e., individuals report adequate/good to excellent self-management across all five domains of diabetes care). Adolescents in the adaptive self-management group consistently had higher overall self-management scores as well as domain specific self-management scores compared to the maladaptive and mixed self-management groups.

Description of Analyses to Predict Mean Differences in HbA1c

Baseline self-management group membership and changes in self-management patterns were used to separately predict mean differences in glycemic control (i.e., HbA1c) six, 12, 18, and 24 months post-baseline using Between-Subjects Analysis of Variance (ANOVA). Post hoc comparisons were performed using Tukey’s Honestly Significant Difference (HSD) test.

Clinically-Relevant Prediction of Glycemic Control Above and Below American Diabetes Association Standards

Chi-square analyses were used to evaluate clinically-relevant differences in glycemic control for self-management groups observed at baseline as well as changes in self-management patterns. Glycemic control was evaluated based on whether the individual met or did not meet recommendations for glycemic control levels based on American Diabetes Association (ADA) standards for pediatrics [13] (i.e., for ages 9–12 years: recommendations for HbA1c are 8% or below; ages 13–19 years: 7.5% or below). These recommendations are typically used to target at risk patients for interventions to improve glycemic control [14, 20].

Results

Prediction of Mean Differences in Glycemic Control Based On Single Point and Changes in Self-Management Clusters across Two Years

Descriptive statistics for glycemic control and *F* statistics for significant tests of mean differences in glycemic control between self-management groups are reported in Tables 2 (cross-sectional self-management patterns) and 3 (changes in self-management patterns).

Relationship of Self-Management Patterns at One and Two Years to Average Glycemic Control (Table 2)—Separate self-management clusters were generated for baseline [12], one, and two years. Table 2 provides the average glycemic control across time for maladaptive, mixed, and adaptive self-management groups based on youth, maternal, and paternal perceptions of adolescent self-management at baseline, and one and two years post-baseline. We examined whether baseline self-management patterns predicted glycemic control from six to 24 months post-baseline; whether self-management at one year predicted glycemic control from 12 to 24 months; and if self-management at two years predicted glycemic control at two years. The percentages of individuals in each self-management group are also provided. As shown in Table 2, maternal reporters' perception of adolescent self-management group membership at baseline, and one and two years post-baseline significantly predicted mean differences in HbA1c at all later points in time. The maternal-reported adolescent adaptive self-management group at baseline, one, and two years also had a significantly lower HbA1c at all later timepoints compared to the other two groups. However, youth and paternal reporters' perceptions of youth self-management inconsistently predicted mean differences in HbA1c over time (see Table 2).

Relationship of Changes in Patterns of Self-Management across Two Years to Average Glycemic Control (Table 3)—Perceived adolescent self-management patterns from baseline to 24 months were separately examined for youth, maternal, and paternal reporters to determine if adolescents' self-management patterns remained relatively consistent over time or if adolescents' self-management became more or less adaptive over time. We examined whether changes in self-management at baseline and two years predicted the adolescents' glycemic control from six to 24 months post-baseline (see Table 3: Longitudinal HbA1c results for Self-Management Patterns from Baseline to Two Years). We also examined whether yearly self-management patterns (baseline to one year; one year to two years) predicted mean differences in HbA1c at later points in time (see Table 3).

The following subgroups that described changes in self-management were identified: individuals whose self-management patterns were consistently maladaptive, mixed, or adaptive over time; and, individuals whose self-management patterns became more or less adaptive over time. Table 3 provides the average glycemic control across time for each of the five subgroups as well the percentages of individuals that were in each self-management group from baseline to one year, baseline to two years, and one to two years. As shown in Table 3, changes in adolescent self-management patterns based on maternal perceptions across yearly intervals (baseline and one year; one and two years) as well as across the entire two years (baseline versus two year self-management patterns) significantly predicted mean differences in adolescents' glycemic control across the two year period. As shown in Table 3, those adolescents' whose maternal caregivers perceived as having consistently maladaptive self-management across time also had much higher HbA1c values and hence worse glycemic control over time compared to adolescents' with consistently adaptive patterns of self-management.

However, youth and paternal caregivers' perceptions of changes in self-management patterns over time inconsistently predicted mean differences in youths' glycemic control across the two year period. As shown in Table 3, youths' changes in self-management patterns from baseline to one year significantly predicted mean differences in HbA1c from baseline to 18 months: those with consistently maladaptive self-management across the first year of the study also had significantly higher HbA1c over time compared to those with more adaptive self-management patterns. Paternal caregivers' perceptions of youths' self-management patterns from baseline to one year did not predict mean differences in HbA1c across the two years (all $p > .05$). Similarly, youths' and paternal caregivers' changes in self-management patterns across the two years (i.e., baseline versus two years) as well as during

the last year of the study (i.e., one versus two year self-management patterns) suggested that youths' and paternal caregivers' perceptions of self-management patterns did not reliably predict mean differences in HbA1c (all $p > .05$).

Prediction of Individuals with Clinically Relevant Differences in Glycemic Control Based On Longitudinal and Baseline Self-Management Clusters

Relationship of Baseline Self-Management Patterns to Clinically-Relevant Levels of Glycemic Control (Figure 1)—Chi-square analyses also revealed a statistically significant association between maternal baseline self-management cluster membership and individuals with clinically relevant differences in HbA1c at subsequent timepoints (6 months: $\chi^2 (2, N = 190) = 11.0, p < .01$; 12 months: $\chi^2 (2, N = 218) = 13.8, p < .01$; 18 months: $\chi^2 (2, N = 200) = 11.2, p < .01$; 24 months: $\chi^2 (2, N = 218) = 20.4, p < .01$). Figure 1 provides the percentages of youth with glycemic control within and above ADA recommendations for each maternal self-management group and mean levels of glycemic control for each group. As shown in Figure 1, those youth who were perceived by maternal caregivers as having maladaptive or mixed self-management patterns at baseline also had a higher percentage of HbA1c values above ADA recommendations from six months to two years post-baseline compared to those with adaptive self-management patterns. However, significant associations between baseline patterns of self-management and subsequent glycemic control six and 24 months post-baseline were not observed for youth reporters (all $p > .05$); nor for paternal reporters (all $p > .05$). However, for both youth and paternal reporters there was a higher percentage of youth with maladaptive self-management whose HbA1c was above clinical recommendations.

Relationship of Changes in Patterns of Self-Management to Clinically-Relevant Levels of Glycemic Control (Figure 2)—Chi-square analyses revealed a statistically significant association between maternal reporters' changes in adolescents' perceived self-management patterns from baseline to two years and adolescents' with clinically relevant differences in HbA1c at 18 ($\chi^2 (4, N = 190) = 11.1, p < .05$) and 24 months ($\chi^2 (4, N = 212) = 21.7, p < .01$). Figure 2 provides the percentages of youth with glycemic control within and above ADA recommendations and the average glycemic control level for changes in self-management (maternal reporters) from six to 24 months. As shown in Figure 2, across the two year period, there was a higher percentage of youth with HbA1c values above the recommended pediatric target ranges set forth by the ADA in the self-management groups that demonstrated consistent maladaptive self-management patterns and the group whose self-management became less adaptive from baseline to two years compared to those adolescents' whose self-management was adaptive from baseline to years and those whose self-management patterns became more adaptive from baseline to two years. Associations between youth and paternal caregivers' perceptions of youth self-management patterns at baseline and two years and clinically relevant differences in HbA1c from six to 24 months were not significant at all timepoints ($p > .05$). However, for youth and paternal reporters there was a higher percentage of youth with consistently maladaptive self-management whose HbA1c was above clinical recommendations.

Discussion

To our knowledge, this is the first study to report individual differences in self-management patterns in a prospective study and document the predictive relationship of individual differences in self-management patterns for subsequent glycemic control six to 24 months later in a sample of youth with type 1 diabetes. To our knowledge, this also is the first study to provide evidence that self-management patterns observed at baseline among youth with type 1 diabetes remain relatively consistent over two years and that both changes in self-

management patterns and those observed at a single point in time predict glycemic control at later points in time. Furthermore, these findings suggest that maternal caregivers are the most accurate at reporting adolescent diabetes self-management behaviors and that their reports' of self-management were most predictive of mean differences in their adolescents' HbA1c across two years as well as clinically meaningful differences in HbA1c over time. Our findings are consistent with studies documenting the relationship of average scores on self-management behaviors to glycemic control in adolescents [2, 11, 21, 22] but advance previous research by demonstrating the prediction of glycemic control based on individual patterns of self-management in several different domains of diabetes management in a multisite sample of youth with type 1 diabetes over the course of a two year follow-up.

Such data are important because they provide new information about individual differences in the pattern of deterioration in the quality of self-management, treatment adherence, and glycemic control that has been consistently observed among adolescents with type 1 diabetes [1–6]. In the present study, three types of self-management patterns were observed for youth and their parental respondents' at one and two years post-baseline that were similar to those described at baseline [12]. There was a group that demonstrated consistently adaptive self-management: "adaptive," a group that demonstrated significantly mixed self-management patterns: "mixed," and a group that demonstrated consistently low or poor self-management: "maladaptive." For maternal reporters, the adaptive self-management group had youth with significantly better glycemic control at subsequent time points compared to those who rated youth as having maladaptive or mixed self-management patterns. Moreover, youth who were rated by their mothers as having maladaptive or moderate/mixed self-management from 12 to 24 months had more HbA1c values above ADA recommendations [13] from 12 to 24 months compared to those who were rated as having adaptive self-management.

These findings have useful clinical implications: First, according to our findings, a high percentage of adolescents' self-management patterns based on both self-report and parental perceptions indicate that self-management patterns remained relatively consistent across a two year period from baseline to two years (ages 9–14 years). A higher percentage of adolescents had more maladaptive or mixed patterns of self-management over time compared to those with consistent adaptive patterns of self-management.

These findings also had important implications for understanding adolescents' glycemic control over time. Those who reportedly had maladaptive self-management patterns also had deteriorating glycemic control over the two year period compared to those who reportedly had better self-management across a number of self-management domains. In fact, those adolescents who reportedly had maladaptive or mixed patterns of self-management had average glycemic control values above that recommended by the American Diabetes Association (i.e., 1 to 1.5% above recommendations) [10, 13]. Problematic glycemic control puts individuals at an increased risk for developing both microvascular and macrovascular diabetes-related complications in adulthood (e.g., cardiovascular problems; problems with eyes, kidneys, and peripheral and autonomic nervous system, etc.) [10]. Research conducted by the Diabetes Control and Complications Trial and its follow-up studies (e.g., Epidemiology of Diabetes Interventions and Complications) suggested that there is a strong relationship between the risk for retinopathy and neuropathy and mean HbA1c over time: a 10% decrease in HbA1c (e.g., 9.0% to 8.1%) was associated with a 39% risk reduction for retinopathy and a 25% risk reduction for microalbuminuria (i.e., neuropathy; [9]).

Second, these findings demonstrated that individual differences in patterns of self-management at baseline and across a two year period predict clinically relevant differences in glycemic control in a sample of youth who are at the cusp of adolescence. Our findings

indicate that some of the variation in glycemic control during early adolescence may be related to individual patterns of self-management. Additionally, our findings suggest that individual differences in diabetes self-management should be assessed at multiple time points during adolescence and that adolescents who demonstrate consistent, problematic diabetes management are at a higher risk for worse glycemic control over time.

Another salient finding was that maternal reports of youth's self-management were the most predictive of glycemic control across time. The predictive power of maternal reports may reflect mothers' prior and continuing monitoring of their children's diabetes management throughout childhood and early adolescence [23], greater access to their children's diabetes management than fathers, and their concern with their children's future health status. Fathers may not be as aware of their young adolescent's patterns of self-management given different demands and roles in the family. Finally, adolescents may overemphasize positive aspects of their self-management based on defensiveness and inconsistent awareness of the importance of their self-management for glycemic control [1].

Several limitations of the present study should be considered. Because the sample has a restricted age range (early adolescence), findings may not be applicable to older adolescents whose parents may not be monitoring diabetes management as closely. There also was a somewhat restricted socioeconomic status and the sample overrepresented Caucasian, two parent families'. On the other hand, the findings were based on a multisite study, which enhances their potential generalizability and included 12% of Hispanic youth with type 1 diabetes, which is greater than recent reports of adolescents [24].

To address these limitations, the following is recommended: 1) longer-term follow-up studies that document the predictive validity of subgroups of self-management patterns across longer periods during adolescence; and, 2) cross validation of our findings on samples of youth with type 1 diabetes with a broader range of racial and socioeconomic characteristics.

Clinically relevant implications of our findings include the importance of targeting individual patterns of self-management in ongoing management of type 1 diabetes based on ongoing assessment of self-management patterns based on maternal report in order to guide interventions [11]. For example, practitioners should identify and support and reinforce adaptive patterns of self-management in order to enhance subsequent glycemic control. On the other hand, youth who demonstrate more severe deficits in self-management across multiple domains may benefit from more intensive interventions such as family-centered problem-solving interventions that target specific deficits [20]. Finally, it will be important to evaluate the efficacy of such individualized assessment and targeted intervention strategies in promoting more effective patterns of self-management and enhanced glycemic control in youth with type 1 diabetes.

Acknowledgments

Sources of support: The work reported in this article was funded by the National Institute of Diabetes and Digestive Disease (1R01 DK069486).

The HbA1c data was analyzed by the Diabetes Diagnostic Laboratory (DCD) at the University of Missouri Columbia Health Sciences Center. The efforts of children, adolescents, mothers, and fathers who gave their time and energy to this work are gratefully acknowledged. Finally, data collection and management of this study were facilitated by a talented group of research assistants, including Michelle Eakin, Danielle Rosnov, Erica Sood, Johanna Carpenter, Daniela Fernandez, Jennifer Hernandez, Angeline Merzier, Claire Peterson, Katharina Wetterau, Megan Miller, and Andrea Perry.

References

- Schilling LS, Knafl KA, Grey M. Changing patterns of self-management in youth with type 1 diabetes. *Journal of Pediatric Nursing*. 2006; 21(6):412–424. [PubMed: 17101399]
- Jacobson AM, Hauser ST, Lavori P, Willet JB, Cole CF, Wolfsdorf JI, Dumont RH, Wertlieb D. Family environment and glycemic control: A four year prospective study of children and adolescents with insulin-dependent diabetes mellitus. *Psychosomatic Medicine*. 1994; 56:401–409. [PubMed: 7809339]
- Kovacs M, Goldstone D, Obrosky S, Iyengar S. Prevalence and predictors of pervasive noncompliance with medical treatment among youths with insulin-dependent diabetes mellitus. *Journal of the Academy of Child and Adolescent Psychiatry*. 1992; 31:1112–1119.
- Morris AD, Boyle DI, McMahon AD, Greene SA, MacDonald TM, Newton RW. Adherence to insulin treatment, glycaemic control, and ketoacidosis in insulin-dependent diabetes mellitus: The DARTS/MEMO Collaboration. *Diabetes Audit and Research in Tayside Scotland. Medicines Monitoring Unit. Lancet*. 1997; 350:1505–1510. [PubMed: 9388398]
- Keough L, et al. Self-management of type 1 diabetes across adolescence. *The Diabetes Educator*. 2011; 37(4):486–500. [PubMed: 21602489]
- Jacobson AM, Hauser ST, Lavori P, Willet JB, Cole CF, Wolfsdorf JI, et al. Psychological adjustment to IDDM: 10-year follow-up of an onset cohort of child and adolescent patients. *Diabetes Care*. 1997; 20:811–818. [PubMed: 9135947]
- Hood KK, Peterson CM, Rohan JM, Drotar D. Association between adherence and glycemic control in pediatric type 1 diabetes: A meta-analysis. *Pediatrics*. 2009; 124(6):e1–e9. [PubMed: 19564254]
- Diabetes Control and Complications Trial (DCCT) Research Group. 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. *Journal of Pediatrics*. 1994; 125:177–188. [PubMed: 8040759]
- The Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complication (DCCT/EDIC) Research Group. Epidemiology of Diabetes Interventions and Complications (EDIC): Design, implementation and preliminary results of a long-term follow-up of the Diabetes Control and Complications Trial cohort. *Diabetes Care*. 1999; 22(1):99–111. [PubMed: 10333910]
- Silverstein J, Klingensmith G, Copeland K, Plotnick L, Kauffman F, Laffel L, Deeb L, Grey M, Anderson B, Hozmeister LA, Clark M. Care of children and adolescents with type 1 diabetes. *Diabetes Care*. 2005; 28:186–212. [PubMed: 15616254]
- Schneider S, Iannotti RJ, Nansel TR, Haynie DL, Simons-Morton B, Sobel DO, Zeitsoff L, Clark L, Plotnick LP. Identification of distinct self-management styles of adolescents with type 1 diabetes. *Diabetes Care*. 2007; 30(5):1107–1112. [PubMed: 17322481]
- Rohan JM, Delamater A, Shroff Pendley J, Dolan D, Reeves G, Drotar D. Identification of self-management patterns in pediatric type 1 diabetes using cluster analysis. *Pediatric Diabetes*. 2011; 12:611–618. [PubMed: 21446925]
- American Diabetes Association. Standards of medical care in diabetes. *Diabetes Care*. 2010; 33:S11–S61. [PubMed: 20042772]
- Kichler JC, Kaugars AS, Ellis J, Alemzadeh R. Exploring self-management characteristics in youths with type 1 diabetes mellitus: does membership in a glycemic control category matter? *Pediatric Diabetes*. 2010; 11:536–543. [PubMed: 20144180]
- ISPAD Guidelines 2006–2007. The diagnosis and management of monogenic diabetes in children. *Pediatric Diabetes*. 2006; 7:352–360. [PubMed: 17212604]
- Harris MA, Wysocki T, Sadler M, Wilkinson K, Harvey LM, Mauras N, White NH. Validation of a structured interview for the assessment of diabetes self-management. *Diabetes Care*. 2000; 23(9):1301–1304. [PubMed: 10977022]
- Steele RG, Aylward BS. The use of cluster analytic techniques in developmental and behavioral pediatric research. *Journal of Developmental and Behavioral Pediatrics*. 2007; 28(4):327–329. [PubMed: 17700085]

18. Garson, GD. Cluster Analysis. Statnotes: Topics in Multivariate Analysis 2010 01/29/2010. <http://faculty.chass.ncsu.edu/garson/pa765/statnote.htm>
19. Aldenderfer, MS.; Blashfield, RK. Cluster Analysis. In: Sullivan, JLN.; RG, editors. Quantitative Applications in the Social Sciences. Vol. 44. Beverly Hills: Sage Publications, Inc; 1984.
20. Wysocki T, Harris MA, Buckloh LM, Mertlich D, Lochrie AS, Mauras N, et al. Randomized controlled trial of behavioral family systems therapy for diabetes: Maintenance of effects on diabetes outcomes in adolescents. *Diabetes Care*. 2007; 30:555–560. [PubMed: 17327320]
21. Jacobson AM, Hauser ST, Lavori P, Willet JB, Cole CF, Wolfsdorf JI, Herskowitz R, Milley J, Bliss R, Gelfand E, Wertlieb D, Stein J. Adherence among children and adolescents with insulin-dependent diabetes mellitus over a four-year longitudinal follow-up: I. The influence of patient coping and adjustment. *Journal of Pediatric Psychology*. 1990; 15:511–526. [PubMed: 2258798]
22. Tamborlane WV, Gatcomb P, Held N, Ahern J. Implications of the DCCT results in treating adolescents with type 1 diabetes. *Clinical Diabetes*. 1994 Sep-Oct;:115–116.
23. Dashiff C, Vance D, Abdullatif H, Wallander J. Parenting, autonomy and self-care of adolescents with type 1 diabetes. *Child: Care, Health, and Development*. 2008; 35 (1):79–88.
24. Ingerski LM, Anderson BJ, Dolan LM, Hood KK. Blood glucose monitoring and glycemic control in adolescence: Contribution of diabetes-specific responsibility and family conflict. *Journal of Adolescent Health*. 2010; 47(2):191–197. [PubMed: 20638012]

Figure 1.

Maternal Reports of Self-Management Patterns at Baseline: Relationship to Clinically Relevant Differences in Glycemic Control from six to 24 months.

Note: Within range = mean HbA1c value of youth whose HbA1c was below ADA recommendations at that timepoint; Above range = mean HbA1c value of youth whose HbA1c was above ADA recommendations at that timepoint; Percentages are the percentage of youth included in this category; * = Group differences observed ($p < 0.05$) between within range and above range comparisons at that time point.

Figure 2.

Maternal Reports of Changes in Self-Management Patterns from Baseline to Two Years: Relationship to Clinically Relevant Differences in Glycemic Control.

Note: Within range = mean HbA1c value of youth whose HbA1c was below ADA recommendations at that timepoint; Above range = mean HbA1c value of youth whose HbA1c was above ADA recommendations at that timepoint; Percentages are the percentage of youth included in this category; * = Group differences observed ($p < 0.05$) between within range and above range comparisons at that time point.

Table 1

Demographic Characteristics from Baseline to 24 months

	Baseline			One Year			Two Year		
	n (%)	Mean (SD); Range	n (%)	Mean (SD); Range	n (%)	Mean (SD); Range	n (%)	Mean (SD); Range	
Child Age (years) *		10.54 (.94); 9.0–12.09				11.59 (.97); 9.86–13.22		12.62 (.96); 10.95–14.39	
Duration of diabetes (years)		4.41 (2.46); 1–11				5.43 (2.49); 2–12		6.46 (2.43); 3–13	
HbA1c		8.20 (1.37); 5.7–16.8%				8.31 (1.38); 5.6–14.5		8.51 (1.41); 5.7–13.4	
Child Gender									
Male	109 (45.61)		103 (45.6)				104 (46.2)		
Female	130 (54.39)		123 (54.4)				121 (53.8)		
Child Ethnicity									
Non-Hispanic, Caucasian	178 (74.5)		171 (76)				170 (76.9)		
Non-Hispanic, African-American	11 (4.6)		11 (4.9)				11 (5.0)		
Non-Hispanic, Multiple Races	13 (5.4)		12 (5.3)				12 (5.4)		
Non-Hispanic, Other	9 (3.8)		5 (2.2)				1 (0.5)		
Hispanic, Caucasian	27 (11.3)		25 (11.1)				26 (11.8)		
Hispanic, Other	1 (0.4)		1 (0.4)				1 (0.4)		
Insulin Regimen									
Conventional	3 (1.3)		7 (3.1)				7 (3.1)		
Multiple Daily Injection	104 (43.5)		69 (30.5)				60 (26.7)		
Pump	126 (52.7)		143 (63.3)				147 (65.3)		
Pod	6 (2.5)		6 (2.7)				7 (3.1)		
Insurance Type									
Private	179 (74.9)								
Public (Medicare/Medicaid)	45 (18.8)								
No insurance	1 (0.4)								
Unknown	14 (5.9)								
Maternal Caregiver Relationship									

	Baseline		One Year		Two Year	
	n (%)	Mean (SD); Range	n (%)	Mean (SD); Range	n (%)	Mean (SD); Range
Biological mother	228 (97.4)	-----	207 (92)	-----	209 (92.9)	-----
Adoptive mother	2 (0.9)	-----	2 (0.9)	-----	2 (0.9)	-----
Step-mother	0 (0)	-----	1 (0.4)	-----	2 (0.9)	-----
Grandmother	4 (1.7)	-----	4 (1.7)	-----	4 (1.7)	-----
<i>Paternal Caregiver Relationship</i>						
Biological father	133 (93.7)	-----	122 (54.2)	-----	123 (54.7)	-----
Adoptive father	4 (2.8)	-----	4 (1.8)	-----	2 (0.9)	-----
Step-father	4 (2.8)	-----	3 (1.3)	-----	4 (1.8)	-----
Grandfather	0 (0)	-----	0 (0)	-----	1 (0.4)	-----
Other	1 (0.7)	-----	1 (0.4)	-----	2 (0.8)	-----
Annual Household Income	-----	\$49,000-\$72,999	-----	-----	-----	-----

* Note: four children were recruited at age 11, but were not seen for baseline visits until after they turned 12 years of age due to study visit cancellations and reschedules

Prediction of Average Levels of Glycemic Control (HbA1c) Based on Youth, Maternal, and Paternal Self-Management (SM) Clusters at Baseline, One, and Two Years.

Table 2

		Glycemic Control from 6–24 monthsfor Baseline SM Clusters				Glycemic Control 12–24 monthsfor One Year SM Clusters				Glycemic Control at 24 months for Two Year					
Reporter	Pattern of Self-Management	6 months		12 months		18 months		24 months		12 months		18 months		24 months	
		%in SM Group	M (SD), n	M (SD), n	M (SD), n	M (SD), n	M (SD), n	% in SM Group	M (SD), n	M (SD), n	M (SD), n	% in SM Group	M (SD), n	M (SD), n	
Mother	Adaptive SM	44.4	7.8 (1.0), 87	7.8 (0.9), 97	8.0 (1.0), 87	8.0 (1.1), 91	22.9	8.1 (1.2), 50	8.2 (1.3), 39	8.3 (1.2), 50	38.2	8.1 (1.2), 83			
Mother	Maladaptive SM	37.6	8.3 (1.4), 69	8.5 (1.4), 81	8.7 (1.6), 75	8.8 (1.6), 77	44.5	8.7 (1.4), 96	8.9 (1.4), 88	8.9 (1.4), 93	26.3	9.0 (1.4), 57			
Mother	Mixed SM	17.9	8.9 (1.7), 34	9.2 (1.8), 40	9 (1.4), 38	9.2 (1.5), 39	32.6	7.8 (1.0), 70	7.9 (1.1), 68	7.9 (1.1), 69	38.5	8.5 (1.4), 76			
Mean Differences in HbA1c: (df) =F			(2,187)=9.5 *	(2,215)=15.2 *	(2,197)=10.0 *	(2,215)=12.3 *		(2,213)=12.3 *	(2,192)=12.0 *	(2,209)=13.6 *		(2,213)=6.6 *			
Youth	Adaptive SM	35.1	8.3 (1.2), 67	8.2 (0.9), 80	8.4 (1.1), 76	8.4 (1.2), 79	23.6	8.2 (1.2), 119	8.2 (1.2), 111	8.4 (1.2), 120	31.5	8.3 (1.3), 70			
Youth	Maladaptive SM	24.7	8.3 (1.5), 45	8.7 (1.8), 55	8.8 (1.7), 53	8.7 (1.6), 53	22.7	8.9 (1.7), 51	8.9 (1.5), 45	8.7 (1.4), 49	24.3	8.8 (1.3), 54			
Youth	Mixed SM	40.2	8.1 (1.3), 83	8.2 (1.4), 88	8.3 (1.4), 76	8.4 (1.4), 79	53.8	8.1 (1.2), 53	8.5 (1.6), 46	8.6 (1.7), 50	44.1	8.5 (1.5), 97			
Mean Differences in HbA1c: (df) =F			p > .05	p > .05	p > .05	p > .05		(2,220)=6.5 *	(2,199)=3.4 **	p > .05		p > .05			
Father	Adaptive SM	35.5	7.6 (0.8), 40	7.9 (0.9), 48	8.2 (1.3), 45	8.2 (1.4), 46	28.8	7.9 (1.2), 42	8.0 (1.4), 38	8.2 (1.6), 42	43.7	8.2 (1.4), 58			
Father	Maladaptive SM	27.0	8.5 (1.7), 35	8.5 (1.6), 37	8.8 (1.6), 37	8.6 (1.4), 32	38.6	8.5 (1.5), 51	8.7 (1.4), 45	8.6 (1.3), 49	39.3	8.6 (1.3), 53			
Father	Mixed SM	37.6	7.8 (1.1), 44	8.0 (1.4), 48	8.1 (1.3), 43	8.2(1.4), 46	32.6	7.9 (1.2), 37	8.1 (1.4), 34	8.2 (1.5), 38	17.0	8.3 (1.4), 23			
Mean Differences in HbA1c: (df) =F			(2,116)=4.8 *	p > .05	(2,122)=3.1 **	p > .05		(2,127)=3.1 **	(2,114)=3.3 **	p > .05		p > .05			

* Fstatistically significant $p < .01$;

** Fstatistically significant $p < .05$

Table 3

Prediction of Average Levels of Glycemic Control (HbA1c) Based on Changes in Patterns of Self-Management (SM) from Baseline to Two Years.

Specific Self-Management Patterns Baseline ⁰ to 12 months ¹²			Baseline M (SD), n	6 months M (SD), n	One Year M (SD), n	18 months M (SD), n	Two Years M (SD), n
Reporter	% of Individuals in SM Group	Longitudinal HbA1c Results for Self-Management Patterns from Baseline ⁰ to One Year ¹²					
Mother	Adaptive SM Baseline to 12 months	14.9	7.7 (1.1), 32	8.0 (1.2), 29	7.9 (.92), 32	7.9 (.99), 23	8.1 (1.1), 32
	Maladaptive SM Baseline to 12 months	19.5	8.5 (1.8), 41	8.5 (1.5), 34	8.7 (1.6), 42	9.0 (1.8), 39	9.0 (1.7), 41
	Mixed SM Baseline to 12 months	1.9	7.3 (.47), 4	7.2 (.4), 4	7.2 (.39), 4	7.2 (1.8), 4	7.0 (.6), 4
	Less Adaptive to More Adaptive SM Baseline to 12 months	17.7	8.2 (1.3), 38	8.3 (1.7), 30	8.3 (1.4), 38	8.3 (1.3), 34	8.4 (1.3), 38
	More Adaptive to Less Adaptive SM from Baseline to 12 months	46	8.1 (1.0), 99	8.1 (1.1), 78	8.2 (1.3), 97	8.3 (1.1), 92	8.4 (1.3), 94
Mean Differences in Glycemic Control: (df = F)			(4,209) = 2.5**	(4,170) = 1.4	(4,208) = 2.6**	(4,187) = 4.0*	(4,204) = 3.6*
Youth	Adaptive SM Baseline to 12 months	22	7.9 (.99), 55	8.2 (1.3), 43	8.1 (.90), 52	8.4 (.98), 51	8.4 (1.3), 53
	Maladaptive SM Baseline to 12 months	11	9.1 (2.2), 26	8.7 (1.8), 21	9.4 (2.2), 26	9.2 (1.8), 24	9.0 (1.7), 25
	Mixed SM Baseline to 12 months	10	7.7 (.78), 24	7.7 (.91), 24	7.8 (1.1), 24	8.1 (1.4), 21	8.3 (1.9), 22
	Less Adaptive to More Adaptive SM Baseline to 12 months	34	8.1 (1.2), 81	8.0 (1.3), 65	8.2 (1.4), 81	8.2 (1.5), 72	8.5 (1.4), 80
	More Adaptive SM to Less Adaptive SM from Baseline to 12 months	17	8.3 (1.3), 40	8.5 (1.2), 31	8.3 (1.0), 40	8.7 (1.3), 34	8.5 (1.1), 39
Mean Differences in Glycemic Control: (df = F)			(4,218) = 4.8*	(4,179) = 2.6**	(4,218) = 5.5*	(4,197) = 2.4**	(4,214) = .95
Specific Self-Management Patterns Baseline ⁰ to 24 months ²⁴			Longitudinal HbA1c Results for Self-Management Patterns from Baseline ⁰ to Two Years ²⁴				
Mother	Adaptive SM Baseline to 24 months	24.9	7.7 (.96), 53	7.9 (1.1), 44	7.8 (.87), 50	7.9 (.94), 44	7.9 (1.0), 50
	Maladaptive SM Baseline to 24 months	14.1	8.6 (2.0), 29	8.6 (1.7), 20	8.9 (1.7), 30	9.0 (1.6), 28	9.0 (1.4), 30
	Mixed SM Baseline to 24 months	6.6	8.8 (.97), 14	8.6 (.72), 10	9.3 (1.8), 14	9.0 (1.1), 13	9.0 (.97), 14
	Less Adaptive to More Adaptive SM Baseline to 24 months	25.8	8.2 (1.2), 54	8.3 (1.5), 47	8.3 (1.3), 54	8.5 (1.6), 49	8.6 (1.6), 54
	More Adaptive to Less Adaptive SM from Baseline to 24 months	28.6	8.0 (1.0), 61	8.0 (1.2), 53	8.1 (1.0), 60	8.3 (1.1), 56	8.5 (1.3), 60
Mean Differences in Glycemic Control: (df = F)			(4,206) = 3.9**	(4,169) = 1.7	(4,203) = 6.6*	(4,185) = 4.1*	(4,207) = 4.5*

Reporter	Specific Self-Management Patterns Baseline ⁰ to 12 months ¹²	% of Individuals in SM Group	Baseline M (SD), n			Two Years M (SD), n		
			6 months M (SD), n	One Year M (SD), n	18 months M (SD), n			
Longitudinal HbA1c Results for Self-Management Patterns from Baseline ⁰ to One Year ¹²								
Reporter	Specific Self-Management Patterns 12 months ¹² to 24 months ²⁴		Longitudinal HbA1c Results for Self-Management Patterns from One ¹² to Two Years ²⁴					
Mother	Adaptive SM 12 months to 24 months	12.9		8.1 (1.4), 27	8.1 (1.2), 20		8.2 (1.3), 27	
	Maladaptive SM 12 months to 24 months	16.2		9.0 (1.5), 34	9.1 (1.4), 32		9.2 (1.5), 34	
	Mixed SM 12 months to 24 months	11.4		7.8 (.91), 24	8.0 (1.1), 22		8.0 (1.2), 24	
	Less Adaptive to More Adaptive SM 12 months to 24 months	43.3		8.2 (1.3), 89	8.3 (1.3), 86		8.3 (1.3), 90	
	More Adaptive to Less Adaptive SM from 12 months to 24 months	16.2		8.2 (1.1), 34	8.4 (1.3), 29		8.4 (1.1), 34	
Mean Differences in Glycemic Control: (df = F)			(4,203) = 3.7 *	(4,184) = 3.5 *		(4,204) = 4.6 *		

Note: Baseline⁰ = Baseline Self-Management cluster based on reported self-management behaviors at baseline; One Year¹² = One Year Self-Management cluster based on reported self-management behaviors at one year; Two Year²⁴ = Two Year Self-Management cluster based on reported self-management behaviors at two years.

* *F* statistically significant $p < .01$;

** *F* statistically significant $p < .05$