Published in final edited form as:

J Adolesc Health. 2018 February ; 62(2): 219–225. doi:10.1016/j.jadohealth.2017.09.017.

Depressive Symptoms at Critical Times in Youth with Type 1 Diabetes: Following Type 1 Diabetes Diagnosis and Insulin Pump Initiation

Dayna E. McGill, M.D.¹, Lisa K. Volkening, M.A.¹, David M. Pober, Ph.D.¹, Andrew B. Muir, M.D.², Deborah L. Young-Hyman, Ph.D.³, and Lori M. Laffel, M.D., M.P.H.¹

¹Section on Clinical, Behavioral, and Outcomes Research, Pediatric, Adolescent, and Young Adult Section, Joslin Diabetes Center, Harvard Medical School, Boston, MA

²Department of Pediatrics, School of Medicine, Emory University, Atlanta, GA

³Georgia Prevention Institute, Georgia Health Sciences University, Augusta, GA

Abstract

Purpose—Depressive symptoms occur at various times during the lifecycle in persons with type 1 diabetes. We investigated depressive symptoms prospectively in youth with new-onset type 1 diabetes and in those beginning pump therapy.

Methods—Youth with type 1 diabetes (N=96), ages 10–17 years, completed the Children's Depression Inventory (CDI) at baseline, 1, 6, and 12 months after diabetes onset or pump start; scores ≥ 13 indicated clinical elevation. Change in depressive symptoms and association between CDI and hemoglobin A1c (HbA1c) were assessed over one year.

Results—New-onset group (n=54) had HbA1c $11.4 \pm 2.5\%$. Pump group (n=42) had diabetes duration 4.1 ± 3.4 years and HbA1c $8.3 \pm 1.3\%$. Baseline median CDI was 5.0 in both groups and remained low over time (ranging from 2.0–3.5). Most youth (new-onset 72%, pump 81%) scored < 13 at all times. Those with CDI ≥ 13 in month one had 9-fold (CI: 3,28) and 11-fold (CI: 3,38) higher risk of CDI ≥ 13 at 6 and 12 months, respectively, than those with CDI < 13 . New-onset youth with CDI ≥ 13 in month one had higher HbA1c at 6 months ($8.3 \pm 1.7\%$) than new-onset youth with CDI < 13 ($7.2 \pm 1.6\%$, $p=0.04$).

Conclusions—CDI scores over one year were similar in new-onset and pump groups. Youth with elevated CDI in the first month after diagnosis or pump start were significantly more likely to have CDI ≥ 13 at 6 or 12 months, supporting recommendations to screen for depressive symptoms

Corresponding author: Lori M. Laffel, M.D., M.P.H., Joslin Diabetes Center, One Joslin Place, Boston, MA, 02215, Phone: 617-732-2603, Fax: 617-309-2451, lori.laffel@joslin.harvard.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conflicts of interest:

The authors report no potential conflicts of interest relevant to this research. None of the authors received any form of payment to produce the manuscript.

due to persistence over time. Those with new-onset diabetes and depressive symptoms in the first month had higher HbA1c at 6 months; confirmatory research is needed.

Keywords

Type 1 diabetes; Adolescent; Depression; New-onset; Insulin pump; Honeymoon; HbA1c

Depressive symptoms are common in the general adolescent population, and even more common in adolescents with chronic disease, especially those with conditions as demanding as type 1 diabetes (1, 2). Reports of the estimated prevalence of depression in adolescents varies from 3–8% (3) to up to 20% (4–6), highlighting the importance of examining depression in teens. Studies indicate that 15–23% of youth with type 1 diabetes meet the cut-off for clinically-elevated depressive symptoms; further, depression disproportionately affects those with lower family income, obesity, older age, and longer duration of diabetes (>10 years) (2, 7–12). The management of type 1 diabetes demands substantial efforts from patients and families, beginning with diagnosis and continuing through transitions to various treatment modalities. Youth with type 1 diabetes exert significant energy each day checking blood glucose levels, administering insulin, and monitoring diet and exercise, in efforts to achieve target glycemic control. The complex relationship between depression and diabetes is likely bidirectional. Depression can negatively impact diabetes self-care and lead to decreased management adherence, poorer glycemic control, diminished quality of life, and increased need for hospitalization (12, 13). Depression and uncontrolled diabetes may both be associated with metabolic derangements with increased systemic inflammation, related to insulin resistance, leading to deteriorating glycemic control and poor outcomes (14, 15).

In contrast to survey assessment, the gold standard for diagnosing depression is a diagnostic interview based on established criteria. Self-report questionnaires are often used in both clinical and research settings to identify depressive symptoms in an efficient and sensitive way; however, these screening tools are not specific, and depressive symptoms detected on self-report surveys should be followed up with clinical interview. Some constructs may overlap with depressive symptoms. In established diabetes, the rigors of self-care can lead to diabetes distress, which is distinct from but often related to depressive symptoms. Most surveys measuring depressive symptoms have been validated in otherwise healthy populations; in patients with diabetes there may be an overlap in depressive symptoms and diabetes distress (16, 17). In new-onset diabetes, it is common for youth to experience adjustment reactions related to coping with the initial stress of the diagnosis of a chronic disease and the symptoms of adjustment reactions, including mild sadness, anxiety, loneliness, and social withdrawal, may overlap with depressive symptoms (18).

Studies have shown that youth with new-onset type 1 diabetes, a time of physiologic and emotional change, exhibit higher rates of depressive symptoms than peers. In a two-year study, Grey and colleagues (7) found that children with new-onset diabetes scored significantly higher on the Children's Depression Inventory (CDI) than peers at baseline (diabetes: 4.7 ± 2.1 , peers: 3.8 ± 2.6). At one year, both groups' scores were non-significantly lower than baseline, and no longer significantly different from one another. Two years later, children with diabetes again had scores that were significantly higher than peers (diabetes:

6.8±2.6, peers: 3.7±1.9). Although absolute CDI scores were low in both groups, 20% of subjects with type 1 diabetes scored above the clinical cut-off of 13 at two years post-diagnosis, compared with only 7.5% of controls. In a cohort of youth followed for six years after diagnosis, Kovacs et al (19) studied depressive symptoms over time. At the initial visit, mean CDI score was 6.52±4.55; in the years that followed, mean CDI scores changed slightly from year to year, but mean scores remained <3.5 for the entire follow-up. In a recent large study of 1,026 adolescents with recent-onset type 1 diabetes (duration 10.4±6.5 months), Hood et al found no significant difference in depressive symptoms (measured by the Center for Epidemiological Studies Depression scale, CES-D) at one year compared to baseline (20).

Depressive symptoms are also common in youth with established type 1 diabetes treated with insulin pump therapy. In a study of 372 adolescents in Poland with established type 1 diabetes treated with pump therapy, Zdunczyk et al found that 18% of participants with hemoglobin A1c (HbA1c) in target range (<7.5%) and 21% of those with HbA1c above target range (≥7.5%) reported depressive symptoms (21). For comparison, another study of teens with established type 1 diabetes followed for one year revealed that those treated with multiple daily injections and those treated with pump therapy had similarly low CDI scores at baseline, 6 months, and 12 months (mean ranging from 2.0 to 2.5) (22).

Most of these studies assessed depressive symptoms in youth with type 1 diabetes using older insulin formulations and technologies. Few recent studies have examined patterns of depressive symptoms in children and adolescents with type 1 diabetes at diagnosis and at initiation of pump therapy, two key stages of the disease and treatment process. Our aim was to investigate level of depressive symptoms and factors associated with report of more depressive symptoms in youth with new-onset type 1 diabetes and in youth beginning insulin pump therapy, and to prospectively follow and compare the course of depressive symptoms in these two groups of youth over one year, an under-studied area to date. We hypothesized that rates of depressive symptoms might be equivalent in the two groups: the new-onset group may be reacting acutely to a new diagnosis, while the pump group may have depressive symptoms related to having a chronic disease.

METHODS

Participants and procedures

This was a secondary analysis of a one-year observational prospective study conducted at 3 pediatric diabetes centers in the U.S. (23). A total of 103 youth ages 10–17 years were identified and recruited within 10 days of diagnosis of type 1 diabetes (n=58) or insulin pump therapy initiation (n=45). Those with psychiatric comorbidities or co-existing disorders affecting weight or metabolism were ineligible. Study visits occurred at baseline, one month, 6 months, and 12 months. Participants only seen at baseline and one month were excluded (n=4 new-onset, n=3 pump) because the pre-specified analysis plan called for assessment of depressive symptoms over time. The final data set included 54 youth in the new-onset group and 42 youth in the pump group. The protocol was approved by each site's Institutional Review Board. Parents/youth provided written informed consent/assent before

beginning any study procedures. Each site performed study procedures according to a unified protocol.

Chart review and interview provided demographic and biomedical data. Baseline data included sex, age, age at diagnosis, race, and family factors (household income, parental marital status, and parental education). Data collected at baseline and across time included height, weight, insulin treatment, and HbA1c. Age- and sex-adjusted body mass index (BMI) percentiles and BMI z-scores (z-BMI) were calculated according to the Centers for Disease Control and Prevention growth charts (24). HbA1c was measured using point of care devices at each site standardized to the Diabetes Control and Complications Trial (DCCT) (reference range 4–6%).

Participants completed the Children's Depression Inventory (CDI) (25) at baseline, one, 6, and 12 months to assess depressive symptoms. The 27-item CDI is a widely-used, validated, self-administered survey that measures cognitive, affective, and behavioral symptoms of depression in youth ages 7 to 17 years. For each item, youth choose one of three statements that best describes their feelings in the past two weeks. Total scores range from 0 to 54; higher scores indicate more depressive symptoms. The CDI has strong internal consistency (Cronbach's alpha 0.70–0.86) (25). For safety, participants were referred for additional evaluation if they responded affirmatively to the CDI question about suicidal ideation (26), or if CDI score was ≥ 19 (14 referrals at baseline, 7 at 1 month, 10 at 6 months, and 11 at 12 months, amounting to 26 unique participants).

Statistical analysis

Statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). Demographic and clinical characteristics are described as means $\pm$ standard deviations or medians and interquartile ranges for continuous variables, and as frequencies or proportions for categorical variables. Analysis of the CDI as a continuous variable creates potential for assigning clinical relevance to small differences in CDI scores well within the subclinical range. Therefore, we calculated the proportion of clinically elevated CDI scores (CDI ≥ 13) (2, 7, 9, 11, 12, 21) and moderately elevated CDI scores (CDI ≥ 10) (8) at each time point in order to focus on clinically-meaningful distinctions. Due to the close proximity in time of the baseline and 1-month visits, and because baseline scores may be capturing an acute adjustment reaction, we created an additional variable of those with CDI scores ≥ 13 at baseline, one month, or both (termed first month elevation). Next, we grouped participants by the number of CDI elevations (≥ 13) over the year with a maximum of 3 elevations: first month, 6 months, and 12 months. We calculated risk ratios for CDI elevations at subsequent time points amongst participants with elevated CDI scores in the first month. To test for associations of CDI scores with major baseline variables, we used Wilcoxon, Kruskal-Wallis, Spearman correlation, chi-squared, Fisher's exact tests, and ANOVA.

In order to investigate the effect of time on depressive symptoms while controlling for covariates, we constructed multivariable mixed linear models. Variables for inclusion in the models were specified *a priori* based on clinical relevance and included diabetes group (new-onset or pump), age, sex, HbA1c, and zBMI. Any variable associated with CDI score ($p < 0.10$) in univariate analysis or whose inclusion/exclusion from the model yielded a 15%

or larger change in the estimated coefficient for the primary association of interest, was retained in multivariable models. The model included interaction terms for diabetes group with HbA1c and z-BMI as the new-onset group had natural and expected changes in both glycemic control and weight following the diagnosis of type 1 diabetes and initiation of insulin therapy. Site was included in the model as a random effect variable to account for any heterogeneity among the different recruiting centers. Candidate variables were added to and removed from the model individually and in groups in a systematic fashion until we arrived at a final model optimized for fit and parsimony (assessed by Akaike's Information Criterion (AIC)).

The occurrence of partial remission ("honeymoon period") was assessed in the new-onset group at one, 6, and 12 months by calculating the insulin-dose adjusted HbA1c (IAA1C = total daily dose in units/kg $\times$ 4 + HbA1c); IAA1C $\leq$ 9 indicates partial remission (27). We tested for associations of CDI score elevations, HbA1c, and partial remission at all time points in the new-onset group.

RESULTS

Baseline demographic and diabetes characteristics

Baseline characteristics are shown in Table 1. Youth in the new-onset group (n=54, 37% male, 69% white) were 13.1 ± 2.2 years old; youth in the pump group (n=42, 55% male, 93% white) were 13.4 ± 1.9 years old and had mean diabetes duration of 4.1 ± 3.4 years. By study design, diabetes duration was longer and age at diabetes onset was younger in the pump group than in the new-onset group. As expected based on the pathophysiology of new-onset diabetes, the new-onset group had a higher mean HbA1c and lower mean zBMI than the pump group: HbA1c $11.4 \pm 2.5\%$ vs $8.3 \pm 1.3\%$, $p < 0.0001$; zBMI -0.13 ± 1.37 SDS vs 0.61 ± 0.89 SDS, $p < 0.01$. The pump group had a higher proportion of white participants and a higher proportion of parents with a college education or higher.

Depressive symptoms

Baseline median CDI was 5.0 in both groups [IQR (2.0, 9.0) in new-onset, (3.0, 9.0) in pump]. At each time point in the first year after diagnosis and in the first year of pump therapy, median CDI scores were not significantly different between the two groups, remaining well below the clinical cut-off for depressive symptoms [one month: New-onset 3.0 (0.0, 7.0), Pump 3.5 (0.0, 6.0); 6 months: New-onset 3.5 (2.0, 7.5), Pump 3.0 (1.0, 5.0); 12 months: New-onset 3.0 (1.0, 6.0), Pump 2.0 (0.0, 5.0)]. Distributions of CDI scores at each time point are shown in Figure 1.

Proportions of participants with elevated CDI scores are shown in Table 2. In the first month, 17% of both new-onset participants and those starting pump therapy had CDI scores equal to or above the clinical cut-off of 13. In the new-onset group, there was no difference in the proportions of youth with CDI elevation over time (chi-squared test for overall trend $p = 0.67$). Over time, the prevalence of clinically elevated depressive symptom scores in the pump group decreased non-significantly (5% had elevated CDI scores at 6 months and 7% at 12 months, chi-squared for overall trend $p = 0.14$, Fisher's Exact test comparing 17% at

baseline with 5% at 12 months $p=0.16$). There were no significant differences between groups at any time point. The prevalence of moderate depressive symptoms (CDI ≥ 10) in the first month was similar in the two groups (28% in new-onset, 26% in pump). Both the new-onset and the pump groups maintained similar proportions of teens with CDI scores ≥ 10 over the year of follow-up.

In the new-onset group, 72% of participants had no elevated scores at any time point; in the pump group, 81% of participants had no elevated scores (Figure 2). Participants with new-onset diabetes or initiating pump therapy with at least one elevated CDI score in the first month were significantly more likely to have elevated CDI scores at 6 or 12 months. Overall, there was a 9-fold increased risk of elevated CDI (95% CI: 3, 28) at 6 months and an 11-fold increased risk of elevated CDI (95% CI: 3, 38) at 12 months amongst those with elevated CDI in the first month compared with those who did not have elevated CDI in the first month. There was a 12-fold increased risk of elevated CDI (95% CI: 4, 35) at 12 months amongst those with elevated CDI at 6 months compared with those who did not have elevated CDI at 6 months. This increased risk was also present when evaluating the groups separately.

CDI scores ≥ 13 were not related to sex, age, baseline glycemic control, race, parental marital status, parental education, or household income in either group at baseline, 6 months, or 12 months. In the pump group, those who had elevated baseline CDI scores had a higher baseline mean zBMI score (1.22 ± 0.59 vs 0.49 ± 0.90 , $p=0.045$).

A multivariable mixed model confirmed the similar depressive symptom scores between the new-onset and pump groups. Controlling for age, sex, HbA1c, zBMI, parental education, and group (new-onset or pump), depressive symptoms decreased over time (estimate -0.18 , SE 0.04 , $p<.0001$). Parental education level was the only significant independent predictor of depressive symptoms; parental completion of college or above was associated with less depressive symptoms (estimate -2.28 , SE 0.84 , $p<.01$). The other covariates were not significant independent predictors of depressive symptoms, but they were included because they modified the relationship between time and depressive symptoms.

Partial Remission Period in the New-Onset Group

In the new-onset group at one month ($n=42$), HbA1c was $9.2\pm1.8\%$, daily insulin dose was 0.60 ± 0.21 units/kg, and 10% ($n=4$) of participants were in partial remission based on IAA1C. In the new-onset group at 6 months ($n=47$), HbA1c was $7.4\pm1.6\%$, daily insulin dose was 0.57 ± 0.21 units/kg, and 36% ($n=17$) of participants were in partial remission based on IAA1C. New-onset youth with CDI ≥ 13 in the first month did not have a significantly different baseline HbA1c than new-onset youth with CDI <13 in the first month, but they had a higher HbA1c at 6 months ($8.3\pm1.7\%$) than new-onset youth with CDI <13 in the first month ($7.2\pm1.6\%$, $p=0.04$). Interestingly, all of the new-onset youth in partial remission at 6 months (IAA1C $\leq 9\%$) had CDI scores <13 at 6 months. In other words, none of the 17 new-onset youth with partial remission at 6 months had CDI ≥ 13 at 6 months, compared with 23% of the 30 new-onset youth who displayed intensification of their diabetes (IAA1C $>9\%$) at 6 months ($p<0.05$). Baseline HbA1c did not predict 6-month HbA1c. In the new-onset group at 12 months ($n=50$), HbA1c was $8.1\pm2.1\%$, daily insulin dose was 0.65 ± 0.22

units/kg, and 22% of participants were in partial remission. CDI scores at 12 months were not associated with 6-month or 12-month HbA1c or partial remission at 12 months.

DISCUSSION

In the present study, baseline and longitudinal median CDI scores were low overall, and not significantly different between those with new-onset diabetes and those beginning pump therapy. A multivariable mixed model showed a decrease in depressive symptoms over time in both groups, after controlling for demographic and physiologic factors. The similar CDI scores between these two groups at baseline, followed by a decline over time, may relate to the impact of, and potential overlap with, adjustment reactions in those with new-onset diabetes and disease-related distress in youth with established diabetes, and this will be an important question for future studies. It is possible that mental health referral for those with elevated CDI scores may have contributed to a decrease in depressive symptoms over time; however, these referrals were necessary for safety assessments rather than for therapeutic intervention.

In youth with established type 1 diabetes, the literature has shown that 15–23% score above the clinical cutoff for depressive symptoms (2, 7–12). Our data showed that 17% of participants had CDI elevations in the first month, which was on the lower side of rates that have been reported in the literature of youth with established diabetes; this may reflect hopefulness about a new technology. However, these rates are higher than rates of elevated depressive symptoms in the general population, reflecting either higher levels of depressive symptoms in youth with T1D, or another construct such as diabetes distress. Diabetes distress is common in youth with type 1 diabetes, and can be associated with feelings specific to diabetes management, as well as feelings such as powerlessness and negative social perceptions (28, 29). Some research in type 1 diabetes has suggested that some symptomatology that has previously been classified as depression in adults with type 1 diabetes may in fact be more appropriately classified as diabetes distress (30). Our data showed that a smaller but not statistically significant proportion scored above the clinical cut-off after 6 and 12 months of pump therapy (5% and 7%, respectively). Notably, a number of reports suggest that youth with type 1 diabetes report higher quality of life following initiation of pump therapy (31–34); the lower proportion of teens with clinically significant depressive symptoms in this current report may reflect an improved sense of well-being on pump therapy. Future studies may explore the pattern of depressive symptoms in youth with established type 1 diabetes treated with pump therapy compared with those who do not begin pump therapy.

Seventeen percent of participants with new-onset diabetes endorsed clinically-elevated depressive symptoms, which is consistent with data from the literature in other incident cohorts (7, 19, 20), but higher than rates reported in the general population. This may reflect either higher levels of depressive symptoms in youth at the onset of type 1 diabetes, or another construct such as adjustment reaction. This group merits careful attention, especially given the increased 6-month HbA1c amongst those with CDI ≥ 13 in the first month. Further, the absence of any new-onset patients with clinically elevated depressive symptoms (CDI ≥ 13) at 6 months among those with partial remission at 6 months compared with the

significantly greater proportion of new-onset patients with clinically elevated depressive symptoms among those not in partial remission at 6 months may point to bi-directionality in the associations; more reported depressive symptoms potentially lead to poorer glycemic control and poorer glycemic control potentially leads to more depressive symptoms. These observations may have important psychosocial and physiologic implications warranting further study, for example, related to inflammation, autoimmunity, and depressive symptomatology (14, 15).

Our findings showed increased risk of continued depressive symptoms at 6 and 12 months in those with CDI scores ≥ 13 in the first month after diagnosis or pump initiation. Although the presence of depressive symptoms (based on an elevated score on a screening measure such as the CDI) is distinct from a diagnosis of depression (by clinical interview), these results support the importance of screening, particularly at key stages of the disease and treatment process such as at the time of diagnosis and at initiation of pump therapy. Identifying depressive symptoms early is important as a recent report noted the association of higher CDI scores with less frequent blood glucose monitoring and poorer glycemic control in youth with type 1 diabetes (8, 35, 36). Furthermore, International Society for Pediatric and Adolescent Diabetes (ISPAD) and American Diabetes Association (ADA) guidelines recommend screening for depression in children and adolescents with type 1 diabetes and many recent quality improvement initiatives have focused on screening for depressive symptoms in youth with type 1 diabetes (8, 35, 36). Recently, the ADA released a position statement on the psychosocial care for people with diabetes advocating for consideration of depression screening in all people with diabetes at the initial visit and periodically; the guidelines further suggest evaluation during major disease and life transitions such as insulin pump initiation, and monitoring for 6 months after such a transition (37). Depressive symptoms are one of many psychosocial aspects that must be considered in a person with diabetes. Given potential overlap with related constructs, screening for diabetes burden/distress and adjustment reactions may also be important. Further studies into interventions which may decrease the risk of psychosocial stress in these groups are warranted.

Strengths of our study include the prospective collection of data over one year at multiple sites, leading to a diverse sample. Data were collected at two important periods of transition in youth with type 1 diabetes: diagnosis and initiation of pump therapy. However, we recognize some limitations of the study. By design, data collection was comprehensive in exchange for a larger sample size, offering exploratory analyses but with limitations in power, especially given the many exposure variables. Next, depressive symptoms were assessed using a self-report survey that can be impacted by response bias; however, the CDI is a widely accepted and validated survey. Due to the relatively small size of our sample, we restricted our analyses to the scale's full score rather than the subscales. Additionally, in order to include participants with missing CDI data either at baseline or at month one ($n=8$), and given the close proximity of the baseline and one month visits, we created the unifying variable, termed first month elevation (capturing youth with CDI scores ≥ 13 at baseline, one month, or both). To verify that our findings were consistent regarding CDI elevations in the first month, we confirmed that CDI elevation either at baseline or one month were each individually associated with greater risk of CDI elevation at 6 and 12 months. Given our study objective to compare youth with new-onset T1D and those beginning pump therapy,

we only included measures that were applicable to both groups, and we therefore did not inquire about diabetes distress or diabetes-specific family conflict. Indeed, an additional weakness is the lack of a contemporaneous group of youth with established T1D on stable treatment plans. The overlap between depressive symptoms and distress in those with established diabetes is an important area for future research. The pump group had a higher proportion of white participants and a higher proportion of parents with a college education or higher, reflecting the unequal recruitment of new-onset and pump participants from the different geographical locations (new-onset: 82% south, 19% northeast; pump: 52% south, 48% northeast), and partially explained by differential race distribution amongst pump users compared to the overall population of youth with type 1 diabetes (38). Nonetheless, despite the study's limitations, the prospective nature of data collection in two groups of youth with type 1 diabetes undergoing important transitions contributes to the literature on depression in youth with diabetes.

This report highlights the relatively low, but important, levels of depressive symptoms in young teens and adolescents with new-onset type 1 diabetes and those initiating pump therapy. There may be overlap between depressive symptoms with adjustment reactions in the new-onset group and with diabetes distress in the group with established diabetes starting pump therapy, meriting further investigation. Further, the longitudinal findings related to depressive symptoms and glycemic control during the remission period in the new-onset group suggest a need for future research to better understand the relationship between depressive symptoms and beta cell function in youth with type 1 diabetes.

Acknowledgments

This research was supported by the National Institutes of Health under grants T32DK007260 and P30DK036836, the American Diabetes Association under grant 07-08-CR66, the Katherine Adler Astrove Youth Education Fund, the Maria Griffin Drury Pediatric Fund, and the Eleanor Chesterman Beatson Fund. The content is solely the responsibility of the authors and does not necessarily represent the official views of these organizations. The study sponsors were not involved in designing the study; collecting, analyzing, or interpreting the data; writing the manuscript; or deciding to submit the manuscript for publication.

Abbreviations and Acronyms

CDI	Children's Depression Inventory
HbA1c	hemoglobin A1c
IAA1C	insulin-dose adjusted HbA1c
zBMI	body mass index z-score.

References

1. Borus JS, Laffel L. Adherence challenges in the management of type 1 diabetes in adolescents: prevention and intervention. *Curr Opin Pediatr*. 2010; 22:405–411. [PubMed: 20489639]
2. Hood KK, Huestis S, Maher A, et al. Depressive symptoms in children and adolescents with type 1 diabetes: association with diabetes-specific characteristics. *Diabetes Care*. 2006; 29:1389–1391. [PubMed: 16732028]
3. Prager LM. Depression and suicide in children and adolescents. *Pediatr Rev*. 2009; 30:199–205. quiz 206. [PubMed: 19487428]

4. Rushton JL, Forcier M, Schectman RM. Epidemiology of depressive symptoms in the National Longitudinal Study of Adolescent Health. *J Am Acad Child Adolesc Psychiatry*. 2002; 41:199–205. [PubMed: 11837410]
5. Kessler RC, Avenevoli S, Costello EJ, et al. Prevalence, persistence, and sociodemographic correlates of DSM-IV disorders in the National Comorbidity Survey Replication Adolescent Supplement. *Arch Gen Psychiatry*. 2012; 69:372–380. [PubMed: 22147808]
6. National Institute of Mental Health. [Accessed 4 Aug 2017] Major Depression Among Adolescents. Available at: <https://www.nimh.nih.gov/health/statistics/prevalence/major-depression-among-adolescents.shtml>
7. Grey M, Cameron ME, Lipman TH, et al. Psychosocial status of children with diabetes in the first 2 years after diagnosis. *Diabetes Care*. 1995; 18:1330–1336. [PubMed: 8721933]
8. Corathers SD, Kichler J, Jones NH, et al. Improving depression screening for adolescents with type 1 diabetes. *Pediatrics*. 2013; 132:e1395–e1402. [PubMed: 24127480]
9. Whittemore R, Kanner S, Singleton S, et al. Correlates of depressive symptoms in adolescents with type 1 diabetes. *Pediatr Diabetes*. 2002; 3:135–143. [PubMed: 15016153]
10. Silverstein J, Cheng P, Ruedy KJ, et al. Depressive Symptoms in Youth With Type 1 or Type 2 Diabetes: Results of the Pediatric Diabetes Consortium Screening Assessment of Depression in Diabetes Study. *Diabetes Care*. 2015; 38:2341–2343. [PubMed: 26459274]
11. McGrady ME, Hood KK. Depressive symptoms in adolescents with type 1 diabetes: associations with longitudinal outcomes. *Diabetes Res Clin Pract*. 2010; 88:e35–37. [PubMed: 20451278]
12. Hood KK, Rausch JR, Dolan LM. Depressive symptoms predict change in glycemic control in adolescents with type 1 diabetes: rates, magnitude, and moderators of change. *Pediatr Diabetes*. 2011; 12:718–723. [PubMed: 21564454]
13. Stewart SM, Rao U, Emslie GJ, et al. Depressive symptoms predict hospitalization for adolescents with type 1 diabetes mellitus. *Pediatrics*. 2005; 115:1315–1319. [PubMed: 15867041]
14. Moulton CD, Pickup JC, Ismail K. The link between depression and diabetes: the search for shared mechanisms. *Lancet Diabetes Endocrinol*. 2015; 3:461–471. [PubMed: 25995124]
15. Hood KK, Lawrence JM, Anderson A, et al. Metabolic and inflammatory links to depression in youth with diabetes. *Diabetes Care*. 2012; 35:2443–2446. [PubMed: 23033243]
16. Hosoya T, Matsushima M, Nukariya K, et al. The relationship between the severity of depressive symptoms and diabetes-related emotional distress in patients with type 2 diabetes. *Intern Med*. 2012; 51:263–269. [PubMed: 22293800]
17. Kokoszka A, Pouwer F, Jodko A, et al. Serious diabetes-specific emotional problems in patients with type 2 diabetes who have different levels of comorbid depression: a Polish study from the European Depression in Diabetes (EDID) Research Consortium. *Eur Psychiatry*. 2009; 24:425–430. [PubMed: 19541457]
18. Kovacs M, Feinberg TL, Paulauskas S, et al. Initial coping responses and psychosocial characteristics of children with insulin-dependent diabetes mellitus. *J Pediatr*. 1985; 106:827–834. [PubMed: 3998926]
19. Kovacs M, Iyengar S, Goldston D, et al. Psychological functioning of children with insulin-dependent diabetes mellitus: a longitudinal study. *J Pediatr Psychol*. 1990; 15:619–632. [PubMed: 2283571]
20. Hood KK, Beavers DP, Yi-Frazier J, et al. Psychosocial burden and glycemic control during the first 6 years of diabetes: results from the SEARCH for Diabetes in Youth study. *J Adolesc Health*. 2014; 55:498–504. [PubMed: 24815959]
21. Zdunczyk B, Sendela J, Szypowska A. High prevalence of depressive symptoms in well-controlled adolescents with type 1 diabetes treated with continuous subcutaneous insulin infusion. *Diabetes Metab Res Rev*. 2014; 30:333–338. [PubMed: 24323887]
22. Boland EA, Grey M, Oesterle A, et al. Continuous subcutaneous insulin infusion. A new way to lower risk of severe hypoglycemia, improve metabolic control, and enhance coping in adolescents with type 1 diabetes. *Diabetes Care*. 1999; 22:1779–1784. [PubMed: 10546007]
23. Young-Hyman DL, Peterson CM, Fischer S, et al. Depressive Symptoms, Emotion Dysregulation, and Bulimic Symptoms in Youth With Type 1 Diabetes: Varying Interactions at Diagnosis and

- During Transition to Insulin Pump Therapy. *J Diabetes Sci Technol*. 2016; 10:845–851. [PubMed: 27137457]
24. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat*. 2002; 11:1–190.
 25. Kovacs M. The Children's Depression Inventory (CDI). *Psychopharmacol Bull*. 1985; 21:995–998. [PubMed: 4089116]
 26. Matlock KA, Yayah Jones NH, Corathers SD, et al. Clinical and Psychosocial Factors Associated With Suicidal Ideation in Adolescents With Type 1 Diabetes. *J Adolesc Health*. 2017
 27. Mortensen HB, Hougaard P, Swift P, et al. New definition for the partial remission period in children and adolescents with type 1 diabetes. *Diabetes Care*. 2009; 32:1384–1390. [PubMed: 19435955]
 28. Fisher L, Polonsky WH, Hessler DM, et al. Understanding the sources of diabetes distress in adults with type 1 diabetes. *J Diabetes Complications*. 2015; 29:572–577. [PubMed: 25765489]
 29. Hagger V, Hendrieckx C, Sturt J, et al. Diabetes Distress Among Adolescents with Type 1 Diabetes: a Systematic Review. *Curr Diab Rep*. 2016; 16:9. [PubMed: 26748793]
 30. Fisher L, Hessler DM, Polonsky WH, et al. Prevalence of depression in Type 1 diabetes and the problem of over-diagnosis. *Diabet Med*. 2016; 33:1590–1597. [PubMed: 26433004]
 31. Muller-Godeffroy E, Treichel S, Wagner VM. Investigation of quality of life and family burden issues during insulin pump therapy in children with type 1 diabetes mellitus- a large-scale multicentre pilot study. *Diabet Med*. 2009; 26:493–501. [PubMed: 19646189]
 32. Hirose M, Beverly EA, Weinger K. Quality of life and technology: impact on children and families with diabetes. *Curr Diab Rep*. 2012; 12:711–720. [PubMed: 22903783]
 33. Stahl-Pehe A, Strassburger K, Castillo K, et al. Quality of life in intensively treated youths with early-onset type 1 diabetes: a population-based survey. *Pediatr Diabetes*. 2014; 15:436–443. [PubMed: 25298998]
 34. Lichtenberger-Geslin L, Boudailliez B, Braun K, et al. Does insulin pump therapy improve quality of life and satisfaction in children and adolescents with type 1 diabetes? *Arch Pediatr*. 2013; 20:248–256. [PubMed: 23380034]
 35. Delamater AM, de Wit M, McDarby V, et al. ISPAD Clinical Practice Consensus Guidelines 2014, Psychological care of children and adolescents with type 1 diabetes. *Pediatr Diabetes*. 2014; 15(Suppl 20):232–244. [PubMed: 25182317]
 36. American Diabetes Association. Standards of medical care in diabetes--2017. *Diabetes Care*. 2017; 40:S6–S131. [PubMed: 27979888]
 37. Young-Hyman D, de Groot M, Hill-Briggs F, et al. Psychosocial Care for People With Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care*. 2016; 39:2126–2140. [PubMed: 27879358]
 38. Willi SM, Miller KM, DiMeglio LA, et al. Racial-ethnic disparities in management and outcomes among children with type 1 diabetes. *Pediatrics*. 2015; 135:424–434. [PubMed: 25687140]

IMPLICATIONS AND CONTRIBUTIONS

Depressive symptoms were similar over one year in youth with type 1 diabetes at two important transition points: diagnosis and beginning insulin pump therapy. Youth with depressive symptoms in month one were more likely to experience depressive symptoms at 6 and 12 months, highlighting the importance of depressive symptom screening.

Figure 1. CDI scores at month 0 (A), month 1 (B), month 6 (C), and month 12 (D)
Black bars: new-onset group, gray bars: pump group.

Figure 2. Number of CDI elevations (score ≥ 13)
Black bars: new-onset group, gray bars: pump group.

Table 1

Baseline Characteristics

	<u>NEW-ONSET</u> (n=54)	<u>PUMP</u> (n=42)	<u>P-value</u>
Sex, male	37%	55%	0.08
Current age (years)	13.1 ± 2.2	13.4 ± 1.9	0.57
Age at diabetes diagnosis (years)	13.1 ± 2.2	9.3 ± 3.6	<0.0001
Diabetes duration	4.8 ± 4.2 days	4.1 ± 3.4 years	N/A
HbA1c	11.4 ± 2.5% (101±27 mmol/mol)	8.3 ± 1.3% (67±14 mmol/mol)	<0.0001
BMI z-score (SDS)	-0.13 ± 1.37	0.61 ± 0.89	<0.01
Race, white	69%	93%	<0.01
Parental education, college or above	34%	58%	0.02
Household income, > \$100K/year	15%	32%	0.06
Family structure, two-parent	70%	83%	0.16

All results are expressed as mean ± SD or %

Table 2

Proportion of Subjects with Elevated CDI Scores

	CDI 13		CDI 10	
	New-Onset	Pump	New-Onset	Pump
First month *	17%	17%	28%	26%
6 months	17%	5%	23%	17%
12 months	12%	7%	15%	17%

* First month = Elevated CDI at baseline, 1 month, or both