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Journal

Health Psychology, 34(5)

ISSN

0278-6133

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Publication Date

2015-05-01

DOI

10.1037/hea0000219

Peer reviewed

HHS Public Access

Author manuscript

Health Psychol. Author manuscript; available in PMC 2016 May 01.

Published in final edited form as:

Health Psychol. 2015 May ; 34(5): 522–530. doi:10.1037/hea0000219.

Depressive Symptoms, Daily Stress, and Adherence in Late Adolescents with Type 1 Diabetes

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Abstract

Objective—To examine whether depressive symptoms are associated with greater perceived daily stress and moderate the link between stress severity and poorer daily adherence in late adolescents with Type 1 diabetes (T1D).

Methods—175 late adolescents with T1D completed measures of depressive symptoms and glycemic control during a baseline laboratory assessment. This assessment was followed by a 14-day daily diary during which adolescents rated the severity of general (GS) and diabetes-specific (DSS) stressful events, as well as adherence to their diabetes regimen.

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Results—Multilevel modeling revealed that adolescents with more depressive symptoms reported more severe daily stress and poorer daily adherence on average, and had poorer glycemic control. On days with more severe DSS, but not GS, adolescents reported poorer adherence. This association was moderated by an interaction between depressive symptoms and the mean level of DSS severity experienced across the two week diary. In adolescents with low levels of depressive symptoms, poorer adherence was reported on days with more severe DSS across all levels of mean DSS severity. In adolescents with average or high levels of depressive symptoms, poorer adherence was reported on days with more severe DSS only when mean DSS severity was average or high.

Conclusions—Depressive symptoms are associated with poorer daily adherence and greater stress severity, and interact with mean DSS severity to moderate the link between daily stress and adherence. The results point to the importance of depressive symptoms for understanding associations between stress and adherence during late adolescence.

Keywords

depression; stress; diabetes; health behavior; adolescents; diary methods

Daily adherence to the type 1 diabetes (T1D) regimen is a challenging task for adolescents, who must complete a number of complex daily disease-related tasks, such as monitoring blood glucose levels, administering insulin, and counting carbohydrates (Hood, Peterson, Rohan, & Drotar, 2009) in the face of numerous daily stressors with diabetes management (e.g., forgetting supplies, dealing with negative affect; Berg et al., 2013). Despite the importance of the T1D treatment regimen, adherence and glycemic control worsen across adolescence (Rausch et al., 2012), with just 40% of adolescents engaging in health behaviors that meet treatment targets (Hilliard et al., 2013). Daily adherence in the context of daily stress is made especially difficult as adolescents experience lability in emotions (Larsen, Moneta, Richards, & Wilson, 2002), which is associated with daily blood glucose (Fortenberry, Butler, Berg, Upchurch, & Wiebe, 2009). Some adolescents experience more extreme disruptions in negative affect such as depressive symptoms, which are associated with greater perceived stress (Rao, Hammen, & Poland, 2010) and nonadherence to the diabetes regimen (Hilliard et al., 2011; McGrady & Hood, 2010). Adolescents with depressive symptoms may experience more severe daily stressors associated with diabetes management, which in turn may result in poorer adherence and metabolic control. In the present study, we examine how perceived stress severity may be associated with daily nonadherence in late adolescents experiencing both heightened depressive symptoms (Hilliard et al., 2011) and heightened stress.

Depressive symptoms may be especially important for understanding adherence during late adolescence. The experience of depressive symptoms is common in healthy adolescents (Galambos, Barker, & Krahn, 2006), and even more so in adolescents with T1D (Reynolds & Helgeson, 2011). Depressive symptoms may be at a peak during late adolescence (Galambos et al., 2006), with depression during this time serving as an important risk factor for a number of adult outcomes including lower life satisfaction (Howard, Galambos, & Krahn, 2010). Late adolescence may be an especially difficult time for those with diabetes as they are dealing with various transition issues related to their diabetes (Wysocki, Hough,

Ward, & Green, 1992) in addition to normative transitions in school and family life (e.g., going to college, moving out of parents' home). The relationship between greater depressive symptoms and poorer treatment adherence in adolescents with T1D is well-documented through cross-sectional (Korbel, Wiebe, Berg, & Palmer, 2007) and longitudinal work (Hilliard et al., 2011; Wu et al., 2013). Greater depressive symptoms in adolescents with T1D are associated with poorer glycemic control (McGrady & Hood, 2010), as well as increased risk for diabetes-related complications (e.g., ketoacidosis; Stewart, Rao, Emslie, Klein, & White, 2005). Understanding how depressive symptoms limit adherence and glycemic control is crucial during late adolescence as patterns of serious nonadherence are often maintained over time (Kovacs, Goldston, Obrosky, & Iyengar, 1992; Wysocki et al., 1992).

One factor that may contribute to nonadherence in late adolescents with T1D who experience depressive symptoms is the challenge of effectively responding to high levels of daily stress associated with both management of a chronic illness (i.e., diabetes-specific stress; DSS) and life as a late adolescent (i.e., general stress; GS) (Helgeson, Escobar, Siminerio, & Becker, 2010). Adolescents with T1D frequently experience diabetes-specific daily stressors (e.g., dealing with high and low blood glucose, forgetting their supplies; Berg et al., 2013). Late adolescents more broadly experience GS that is similar in severity to that of adults (APA, 2014) and often related to future-oriented financial and occupational pursuits (Arnett, 2006). When it comes to stress management, late adolescents who perceive stressors as more severe are less likely to engage in healthy behaviors (e.g., physical exercise) and more likely to engage in behaviors that are particularly problematic for those with T1D (e.g., skipping meals, sedentary activities; APA, 2014). Given the importance of such health behaviors to T1D adherence, the ability of adolescents with T1D to appraise everyday stress as less severe and more manageable has important implications for their long-term diabetes outcomes.

Both DSS and GS have demonstrated links with functioning in adolescents with T1D that have implications for adherence. The presence of a greater number of diabetes stressors is associated with increased negative affect and lower perceived control on a daily level in adolescents with T1D (Fortenberry, Wiebe, & Berg, 2011). In a daily diary study of adults with T1D, greater fluctuations in GS severity (hassles) from day to day were associated with higher subsequent levels of HbA1c, even after controlling for individuals' average GS severity across days of the study (Aikens, Wallander, Bell, & Cole, 1992). In cross-sectional work involving a wide age range of adolescents with T1D, more severe GS was associated with poorer adherence to the diabetes treatment regimen, and severity of both DSS and GS were associated with poorer metabolic control (Farrell, Haines, Davies, Smith, & Parton, 2004).

Although the experience of more severe stress is clearly linked with functioning in individuals with T1D, stress may present a particular challenge for adolescents with heightened depressive symptoms given that they utilize less effective coping strategies (Horwitz, Hill, & King, 2011) and have limited problem-solving abilities during times of stress (Adams & Adams, 1991). Unfortunately, both clinical depression and depressive symptoms are associated with a greater number of daily stressors and hassles (McIntosh,

Gillanders, & Rodgers, 2010), and adolescents with clinical depression who perceive acute stress as more severe are at increased risk for a recurrent depressive episode (Rao et al., 2010). Thus, the link between perceived stress and adherence may be most apparent when individuals with depressive symptoms experience high levels of stress severity.

Current Study

Given the daily nature of T1D management, we used a daily diary approach to examine the relationships between depressive symptoms, stress, and adherence in a large sample of adolescents with T1D. Research has demonstrated both between-person (high levels of stress relative to others; Farrell et al., 2004) and within-person (high levels of stress relative to an individual's typical day; Aikens et al., 1992) associations between stress and functioning in individuals with T1D. Thus, we examined within-person (i.e., day-to-day) associations between stress and daily adherence, as well as whether between-person differences in stress and symptoms of depression moderate these associations (see also Hoffman & Stawski, 2009).

We predicted that late adolescents with greater depressive symptoms would perceive more severe daily stress and have poorer daily adherence. Furthermore, we expected that on days when adolescents experienced more severe daily stress their adherence would be poorer, and that this association would be stronger for adolescents with higher levels of mean stress severity as well as for those with greater depressive symptoms. Finally, we expected that adolescents with greater depressive symptoms and more severe mean stress would have poorer glycemic control. Although we examined the severity of DSS and GS separately, we did not expect differences in the pattern of results based on type of stress.

Method

Participants

Participants included 175 late adolescents (113 females, 64.6%) with T1D enrolled in a larger study. Adolescents were recruited through outpatient pediatric endocrinology clinics in two southwestern USA cities (N = 96 and 79 at each site). Eligibility criteria included being diagnosed with T1D for at least one year (years since diagnosis M = 7.46, SD = 3.76), being 17–18 years of age (M = 17.7, SD = 0.38), enrolled in their last year of high school, living in their parental home, not planning to participate in a program or activity that restricted daily contact with parents during the study, and speaking English as their primary language (due to requirements of cognitive testing in the larger study). These adolescents' glycemic control on average did not meet the recommended target of HbA1c levels below 7.5% (American Diabetes Association, 2014; M = 8.19, SD = 1.60); only 35.6% of participants met this target. Additionally, 46.3% of participants used an insulin pump. Consistent with the patient population at participating clinics, the sample was 78.9% non-Hispanic White, 13.9% Hispanic, 4.2% African American, 1.8% Asian/Pacific Islander, and 1.2% American Indian. A range of parent education was reported with 14% of mothers and 18% of fathers having no more than a high school education, 47% of mothers and 31% of fathers having some college without a bachelor's degree, and 39% of mothers and 51% of fathers having a bachelor's degree or higher.

Procedure

Data are from the first of three waves of data collected for a longitudinal study of late adolescents with T1D and their parents. All study procedures were approved by the universities' Institutional Review Boards. Adolescents and their parents provided written informed assent and consent. During the initial session, adolescents completed a battery of neurocognitive and behavioral measures, as well as an HbA1c home test kit, and were trained on online measures to be completed at home. After this visit, adolescents completed an online baseline survey, after which they received an electronic link to the online 14-day diary that they completed at the end of each day. They were instructed to complete the survey and diaries individually. Research assistants contacted each participant nightly via text messages or phone calls to remind and motivate the participant to complete the diary and to solve technical problems as necessary. Adolescents completed an average of 11.4 daily diaries (*SD* = 3.3).

Measures

Depressive symptoms—Participants completed the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977), a 20-item self-report measure of symptoms of depression over the past week. Items were rated on a 0 (*rarely or none of the time*) to 3 (*most or all of the time*) scale, with higher scores indicating greater depressive symptoms. Twelve participants declined to answer one or two items on the CES-D. We calculated these participants' scale scores using the sample mean on missing items. The CES-D demonstrates good internal consistency (excellent in the current sample, $\alpha = 0.93$), moderate test-retest reliability, and correlations with longer clinical measures of depression (Radloff, 1977). Clinical severity categories in adolescents are minimal (0–15), mild (16–23), and moderate/severe (24–60) (Lawrence et al., 2006). Although we examined the CES-D as a continuous measure of depressive symptoms, the current sample of adolescents included 102 (58.3%) in the minimal range, 29 (16.6%) in the mild range, and 44 (25.1%) in the moderate/severe range. These rates of clinically significant depressive symptoms are substantially higher than Lawrence et al.'s (2006) estimates from the SEARCH for Diabetes in Youth study, although their sample included a wider age range of adolescents with both type 1 and type 2 diabetes. The average CES-D score in the current sample was 16.56 (*SD* = 12.43). Females reported greater depressive symptoms than did males (M_{Female} = 17.33, *SD* = 13.07 and M_{Male} = 15.16, *SD* = 11.14) but this difference was not statistically significant, $t(173) = -1.104$, $p = .271$.

Daily stress severity—As part of the daily diary, participants completed a checklist of five general stressful events (argument or disagreement with someone, problem with school or schoolwork, problem with work or chores, having to deal with other people's problems, problem related to where they live or things they own) from the Daily Inventory of Stressful Events (Almeida, Wethington, & Kessler, 2002) and five diabetes-specific stressful events (i.e., problem with high/low blood sugar, forgetting or skipping a blood glucose test, taking wrong amount of insulin, feel bad because of diabetes, problem with pump or continuous blood glucose monitor) derived from coding of open-ended descriptions of mother and adolescent-reported diabetes events (Beveridge, Berg, Wiebe, & Palmer, 2006). Participants rated how stressful each endorsed event was on a 1 (*not at all stressful*) to 5 (*as stressful as*

it can get) scale. For each of the general stressful events endorsed, adolescents were also asked to indicate whether it was related to their diabetes. This was rarely the case for any of the general stressful events: argument or disagreement with someone (5.6%), problem with school or schoolwork (6.8%), problem with work or chores (17.7%), having to deal with other people's problems (1.7%), and problem related to where they live (10.8%).

We examined both daily general stress (GS) severity (mean rating across general stressors) and daily diabetes-specific stress (DSS) severity (mean rating across diabetes stressors). To test between-subject differences in overall severity of stress, we also examined mean stress severity for each type of stress by averaging GS and DSS severity scores across the 14 days of the diary. There were no significant gender differences in mean stress severity, GS $t(173) = -1.049$, $p = .296$ and DSS $t(173) = -1.120$, $p = .264$.

Daily adherence—Participants rated adherence to their diabetes treatment regimen as part of the daily diary. Adherence was measured with 6 items adapted from the Self-Care Inventory (SCI; La Greca, 2004) that assessed adherence behaviors on a scale from 1 (*did not do it at all*) to 5 (*did it exactly as recommended*): checking blood glucose, administering insulin dose as recommended, adjusting insulin based on blood glucose values, having quick-acting sugar available to treat reactions, eating the proper foods or counting all carbohydrates, and using pump or continuous monitor correctly. Items from the SCI were reviewed by a diabetes educator and a pediatric endocrinologist to identify regimen behaviors that should typically occur daily; revisions were made to capture currently recommended daily diabetes behaviors using as few items as possible. Averaged across diary days, this daily measure was correlated with participants' baseline survey responses on the Diabetes Behavior Rating Scale (Iannotti et al., 2006; $r = .65$, $p < .001$) and internal consistency among items was good ($\alpha = .84$).

Glycemic control—Glycemic control was measured using HbA1c assay kits obtained from and processed by CoreMedica Laboratories, which is accredited by the College of American Pathologists (www.coremedica.net). We were missing test kit data from one participant. Test kit data were collected in addition to medical record data in the larger longitudinal study in order to allow for examination of changes in HbA1c over time for those adolescents who did not regularly attend medical appointments. This measure was highly correlated with HbA1c obtained from point of care assays in these adolescents' medical records ($r = .76$, $p < .001$). In addition to our examination of test kit data we also tested study hypotheses using HbA1c from medical records (including $N = 170$ adolescents as we were unable to obtain medical record data from five participants). We found no substantive differences in the direction of effects or significance levels. We therefore report only results of test kit data analyses.

Data Analysis

Primary study hypotheses were tested with multilevel models computed in Hierarchical Linear and Nonlinear Modeling (HLM 7; Raudenbush, Bryk, Cheong, Congdon, & de Toit, 2011). We included gender as a covariate in all analyses (coded −0.5 = *male*, 0.5 = *female*) and tested separate models for GS and DSS severity. To test whether depressive symptoms

were associated with higher levels of stress, we regressed daily stress severity on depressive symptoms and gender, including a random effect on the intercept.

To examine between versus within-person variance in the daily diary, we calculated intraclass correlations (ICCs) for daily adherence and GS and DSS severity from variance estimates obtained from unconditional (empty) models. ICCs indicated that 73% of the variance in adherence, and 29% and 43% of the respective variance in daily GS and DSS, was between-persons. These ICC estimates provide support for the inclusion of mean stress severity in our models (Hoffman & Stawski, 2009). We examined whether depressive symptoms and mean stress severity would each independently moderate the association between daily stress and daily adherence, as well as whether there was a three-way interaction between daily stress severity, mean stress severity, and depressive symptoms. General multilevel models are below.

Level 1 (within-person) equation:

$$\text{Adherence}_{ij}=\beta_{0j}+\beta_{1j}(\text{Daily Stress Severity})_{ij}+\text{r}_{ij}$$

Level 2 (between-person) equation:

$$\begin{aligned}\beta_{0j}=&\gamma_{00}+\gamma_{01}(\text{Depressive Symptoms})_j+\gamma_{02}(\text{Mean Stress Severity})_j+\gamma_{03}(\text{Gender})_j+\\&\gamma_{04}(\text{Depressive Symptoms}\times\text{Mean Stress Severity})_j+\text{u}_{0j}\\\beta_{1j}=&\gamma_{10}+\gamma_{11}(\text{Depressive Symptoms})_j+\gamma_{12}(\text{Mean Stress Severity})_j+\gamma_{13}(\text{Gender})_j+\\&\gamma_{14}(\text{Depressive Symptoms}\times\text{Mean Stress Severity})_j+\text{u}_{1j}\end{aligned}$$

Daily Stress Severity was group (person) mean centered, and Depressive Symptoms and Mean Stress Severity were grand mean centered prior to analyses. The distribution of adherence scores was negatively skewed. To account for the skewness, we reverse scored adherence and reran models with both log and square root transformations (Tabachnick & Fidell, 2013). The pattern of results did not differ; untransformed scores were used for ease of interpretation.

We also ran all models with study site, pump status, and illness duration as additional covariates; as there were no substantive changes in magnitude, direction, or significance of effects testing hypotheses, final models included only gender as a covariate. Results of models including additional covariates are available from the first author.

Results

Table 1 presents descriptive statistics and correlations among glycemic control, mean adherence, depressive symptoms, and mean GS and DSS severity. Of note, average depressive symptoms in the current sample were just above the suggested cutoff for clinically significant depressive symptoms in adolescents (a CES-D score of 16; Lawrence et al., 2006). As expected, greater depressive symptoms were correlated with higher mean stress, poorer adherence, and poorer glycemic control.

Relation of Depressive Symptoms to Daily Stress Severity and Adherence

Our hypothesis that adolescents with greater depressive symptoms would report significantly higher stress severity and poorer adherence was supported. Adolescents with greater depressive symptoms reported more severe daily GS ($B = 0.02$, $SE = 0.00$, $\beta = 0.21$, $p < .001$) and DSS ($B = 0.02$, $SE = 0.00$, $\beta = 0.25$, $p < .001$), as well as poorer daily adherence on average ($p < .001$; see Table 2).

Depressive Symptoms and Mean Stress Severity as Moderators of the Daily Stress Severity and Adherence Relationship

Our hypothesis that depressive symptoms and mean stress severity would moderate the association between higher daily stress severity and poorer adherence was partially supported. There was not a significant association between daily GS and daily adherence. However, more severe daily DSS was associated with poorer daily adherence, an association moderated by an interaction between mean DSS severity and depressive symptoms ($p < .01$). We probed this 3-way interaction using the methods outlined by Preacher, Curran, and Bauer (2006).

Tests of simple slopes in the 3-way interaction—We tested simple slopes at low (−1 *SD*), average (mean), and high (+1 *SD*) values of depressive symptoms (corresponding to CES-D raw scores of 4.16, 16.56, and 29.01) and mean DSS severity (corresponding to raw scores of 1.48, 2.16, and 2.84). Figure 1 presents simple slopes of the association between daily DSS severity and adherence by depressive symptoms and mean DSS severity. Adolescents with low levels of depressive symptoms were less adherent on days with more severe DSS across levels of mean DSS severity (low mean DSS $B = -0.13$, $SE = 0.05$, $p = 0.01$; average mean DSS $B = -0.12$, $SE = 0.03$, $p = 0.0001$; high mean DSS $B = -0.12$, $SE = 0.05$, $p = 0.01$). Adolescents with average levels of depressive symptoms were less adherent on days with more severe DSS if their mean DSS severity level was average or high (average mean DSS $B = -0.10$, $SE = 0.02$, $p = .0001$; high mean DSS $B = -0.17$, $SE = 0.03$, $p = 0$), but not if their mean DSS severity level was low (low mean DSS $B = -0.02$, $SE = 0.04$, $p = 0.5$). Similar to those with average levels of depressive symptoms, adolescents with high levels of depressive symptoms were also less adherent on days with more severe DSS if their mean DSS severity level was average or high (average mean DSS $B = -0.06$, $SE = 0.03$, $p = 0.05$; high mean DSS $B = -0.21$, $SE = 0.03$, $p = 0$), but not if their mean stress severity level was low (low mean DSS $B = 0.08$, $SE = 0.06$, $p = 0.14$). Thus, whereas adolescents with low levels of depressive symptoms were less adherent on high-stress days regardless of how their mean stress compared with peers, adolescents with average or high levels of depressive symptoms (i.e., those reporting symptoms in the mild or moderate/severe clinical range) were only less adherent on high-stress days if they reported similar or more severe mean stress relative to peers.

Regions of significance in the 3-way interaction—In addition to traditional tests of simple effects, we also computed regions of significance using Preacher et al.'s (2006) methods and companion website (http://www.quantpsy.org/interact/hlm3.htm). This approach provides additional information beyond that gleaned from traditional tests of simple effects by calculating the entire *range* of values of a moderator at which simple

effects are significantly different from zero. We examined the values of mean DSS severity at which the association between daily DSS severity and daily adherence was significantly different from zero for adolescents with low, average, and high levels of depressive symptoms. We report the region boundaries for each level of depressive symptoms, as well as the simple slopes at these values using a criterion of alpha = .05 (where $t = -1.98$). Figure 2 presents a plot of the simple slopes for low, average, and high depressive symptoms as a function of mean DSS severity values. Whereas simple slopes were largely consistent for adolescents with low depressive symptoms irrespective of mean DSS severity, they were more strongly associated for adolescents with average and high depressive symptoms who had higher mean DSS severity. The regions at which simple slopes were significantly different from zero are described below.

In adolescents with low levels of depressive symptoms, simple slopes were significant and largely consistent in magnitude for adolescents regardless of their mean DSS severity: associations between daily DSS severity and adherence were significant when mean DSS severity scores were between −1.10 ($B = -0.14$, $SE = 0.07$) and 0.99 ($B = -0.12$, $SE = 0.06$). However, in adolescents with average or high levels of depressive symptoms, simple slopes were only significant when mean DSS severity values were near the sample mean or higher. Simple slopes for adolescents with average levels of depressive symptoms were significant if their mean DSS severity scores were less than −3.25 (a value below the minimum mean DSS severity value in the current sample; $B = 0.24$, $SE = 0.12$), or greater than −0.38 ($B = -0.06$, $SE = 0.03$). Simple slopes for adolescents with high levels of depressive symptoms were significant if their mean DSS severity scores were less than −0.90 ($B = 0.13$, $SE = 0.07$) or greater than 0 ($B = -0.06$, $SE = 0.03$). In summary, although the predicted associations between daily stress severity and adherence were found across the full range of stress severity scores for those with low depressive symptoms, they were only found among those with average or high levels of depressive symptoms when their mean DSS severity values were near the sample mean or higher.

Relation of Depressive Symptoms and Mean Stress Severity to Glycemic Control

Our final hypothesis, that adolescents with greater depressive symptoms and higher levels of mean stress would have poorer glycemic control, was partially supported. Greater depressive symptoms ($B = 0.04$, $SE = 0.01$, $\beta = 0.28$, $p < .001$) and more severe mean DSS ($B = 0.55$, $SE = 0.18$, $\beta = 0.23$, $p = .002$) were associated with higher HbA1c, but more severe mean GS was not significantly associated with HbA1c ($B = 0.01$, $SE = 0.16$, $\beta = 0.00$, $p = .961$).

Discussion

This sample of late adolescents with T1D reported quite high depressive symptoms, and these symptoms were associated with more severe stress, poorer adherence, poorer glycemic control, and differential relationships of daily stress severity with daily adherence. Adolescents with greater depressive symptoms reported more severe daily GS and DSS, as well as poorer daily adherence on average. Contrary to predictions, adolescents did not report significantly poorer adherence on days with more severe *GS*, although they did report poorer adherence on days with more severe *DSS*. This association was moderated by the

interaction between depressive symptoms and mean DSS severity. For adolescents with low depressive symptoms, the association between daily DSS severity and adherence was significant across mean DSS severity levels, but for adolescents with average or high depressive symptoms, the association was present only for those with higher mean DSS severity.

Previous research based on the stress generation model of depression has demonstrated that adolescents with clinical depression perceive heightened levels of stress that function to maintain depressive symptoms and that increase risk for recurrent depressive episodes (Rao et al., 2010). Our results were consistent with this model and associated empirical findings; late adolescents with higher levels of depressive symptoms reported more severe daily GS and DSS. Further, our results demonstrated poorer daily adherence in adolescents with greater depressive symptoms, consistent with previous findings that heightened levels of depressive symptoms are associated with poorer adherence to the T1D treatment regimen (Hilliard et al., 2011; Wu et al., 2013). Given that late adolescents with T1D are often nonadherent to their treatment regimen (Hilliard et al., 2013), it is particularly important to understand malleable factors that, with intervention, might improve adherence and disease outcomes.

Our results suggest that for late adolescents managing T1D, the combination of more severe mean DSS and greater depressive symptoms is particularly challenging. Participants with low levels of depressive symptoms evidenced consistent associations between high-stress days and poorer adherence regardless of level of mean DSS severity. In contrast, adolescents with average or high levels of depressive symptoms (i.e., those in the mild or moderate/severe clinical range of depressive symptoms) evidenced stronger associations between more severe daily stress and poorer daily adherence when their mean stress levels were higher, demonstrating this association only when their mean stress severity level was at or above the sample mean. One possible explanation for the pattern of results for late adolescents experiencing higher depressive symptoms is that these individuals have ineffective coping strategies. Adolescents with higher levels of depression are more likely to report coping strategies such as behavioral disengagement and self-blame (Horwitz, Hill, & King, 2011), and are particularly likely to have limited problem-solving abilities during times of stress (Adams & Adams, 1991). Those experiencing greater depressive symptoms may also have low confidence in their ability to manage disease-related stress and view themselves as less capable of managing stress and tolerating frustrations (Mahon, Yarcheski, Yarcheski, & Hanks, 2007). This lower confidence could relate to a tendency to become more easily derailed in their diabetes management on high-stress days.

Somewhat surprisingly, adolescents reporting depressive symptoms in the clinical range (i.e., average or high levels of depressive symptoms in the current sample) did not evidence associations between daily stress and adherence if they experienced low mean DSS. One possible explanation is that some late adolescents with heightened depressive symptoms are less responsive to their environment, and thus do not evidence associations between daily stress and daily adherence. Previous research has demonstrated that some adolescents with clinically significant depression exhibit less stress reactivity (i.e., less cortisol response) (Oldehinkle & Bouma, 2010). Adolescents with this particular profile tend to recover more

quickly from depressive episodes and be less likely to evidence a recurrent episode, particularly when their overall level of stress is lower (Rao et al., 2010). Although clearly speculative, one explanation of our findings is that our late adolescents with clinically elevated levels of depression had this profile of blunted stress reactivity, making them less impacted by day-to-day fluctuations in stress severity. It is also possible that adolescents with clinically significant depressive symptoms and low levels of mean DSS were simply experiencing atypically low levels of stress during the 14-day diary period. These weeks perceived to be low in stress severity may be unusual (given their generally higher perceptions of stress severity) and experienced as less challenging, resulting in less of a relationship between perceived stress severity and adherence. This was an unexpected finding, and our interpretations are speculative. Future research to examine these possibilities may prove fruitful.

It is important to consider the surprising finding described above alongside our results that late adolescents with low depressive symptoms displayed associations between daily stress and adherence even at low mean DSS levels, but simultaneously displayed better adherence on average than their more depressed counterparts. This pattern raises the possibility that, among those with good emotional resources (i.e., low depressive symptoms), links between daily stress and nonadherence are normative and reflect the ongoing process of daily diabetes management, where daily difficulties serve as feedback to actively cope and problem-solve so that minor hassles do not continue or escalate into larger problems.

Our results demonstrating associations among depressive symptoms, daily DSS, and daily adherence, together with our results linking depressive symptoms and daily DSS with poorer glycemic control, imply that depressive symptoms are problematic for long-term diabetes management. Greater depressive symptoms and more severe mean DSS predicted higher HbA1c, suggesting that the accumulation of the effects of daily DSS on adherence for those displaying depressive symptoms may ultimately be reflected in higher HbA1c. These results should be examined in the context of longitudinal data in order to confirm temporal relationships between depressive symptoms and glycemic control.

Links between stress severity and both adherence and HbA1c were found for DSS but not GS. This may be due to the relevance of the type of stress to our outcomes of interest. Late adolescents' experience of more severe stress related to diabetes events may be particularly salient for diabetes management and control given the necessity that they effectively cope with such events to reduce future occurrences. It is possible that experience of more severe general stress is closely related to poorer general outcomes. For example, the experience of more severe stress related to school or school work may be related to poorer school performance. Additionally, only two of our general stress items were interpersonal in nature (i.e., argument or disagreement with someone, dealing with other people's problems). Given that interpersonal stressors are particularly important in the development and maintenance of depressive symptoms (Rao et al., 2010) as well as in adolescent diabetes management (Helgeson, Lopez, & Kamarck, 2009), it is possible that findings would be different if more interpersonal stressors were examined. Measurement of daily GS with a greater focus on interpersonal stressors, as well as examination of general as well as diabetes outcomes, will aid in understanding these processes.

These results should be interpreted in the context of some limitations. First, depressive symptoms, stress severity, and adherence were all self-report measures and as such method variance may play a role in the findings. Adolescents experiencing more depressive symptoms may have a negative bias in both their severity of stress and adherence reports. We believe this concern is mitigated by the fact that the link between stress severity and adherence was only found for DSS, and that this pattern was also demonstrated in analyses of glycemic control. However, future research utilizing objective measures of daily adherence such as data from glucometers is necessary (Kichler, Kaugars, Maglio, & Alemzadeh, 2012). Second, we cannot determine temporal precedence of stress versus adherence. It is possible that more severe stress preceded poorer adherence, such that it was an inadequate response to stress that in part led to nonadherence to treatment regimen. Alternatively, poorer adherence may have led to a perception of more severe stress. Finally, the demographic characteristics of our sample limit the generalizability of findings. As the larger longitudinal study is examining T1D management during emerging adulthood, our sample included late adolescents in their senior year of high school. This may be an especially challenging time as late adolescents manage the demands of their senior year, apply for college or work, and look toward the more unstructured life outside of high school (Arnett, 2006). The high level of depressive symptoms in the current sample may reflect a peak in depressive symptoms at this unique developmental time point (Galambos et al., 2006). It is possible these results would not replicate in a sample of younger adolescents. Finally, the sample was primarily Caucasian and well-educated, also limiting generalizability of these findings.

Summary and Implications

Late adolescence is an especially relevant time to consider adherence to the T1D treatment regimen as adherence rates are low (Hilliard et al., 2013), depressive symptoms are at their peak (Galambos et al., 2006), and future adult health behavior patterns are developing (Wysocki et al., 1992). Our results demonstrating that depressive symptoms are linked to poorer adherence, heightened stress severity, and poorer glycemic control provide additional support for aims to identify adolescents with depressive symptoms in the context of routine diabetes care (Corathers et al., 2013). Although clinically significant depressive symptoms often decrease following pharmacological or psychosocial interventions delivered to those with T1D, these improvements do not necessarily translate into improvements in diabetes management or outcomes (Markowitz et al., 2011). Our findings further demonstrate the need for a focus on improving skills that may enable adolescents to more effectively cope with stress (e.g., problem-solving skills training). A more explicit focus on stress management and problem-solving skills training in interventions targeting depressive symptoms in late adolescents with T1D may bolster treatment outcomes (i.e., reductions in depressive symptoms) and more effectively improve disease management and outcomes in this vulnerable group. Continued development and improvement of interventions designed to help individuals with T1D effectively manage their illness and associated stress, and simultaneously treat depressive symptoms when present, is important for the mitigation of challenges associated with living with T1D during late adolescence.

Acknowledgments

This research was supported by the National Institute of Diabetes and Digestive and Kidney Diseases at the National Institutes of Health (grant number R01DK092939, co-PIs Berg and Wiebe). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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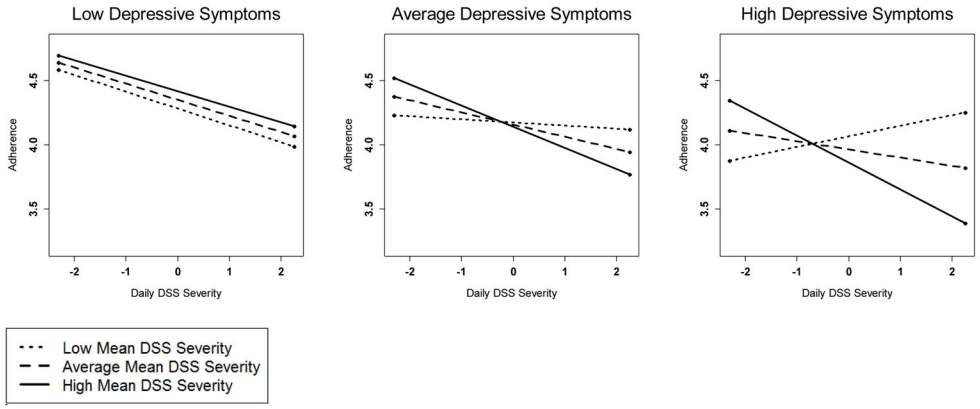

Figure 1. Simple Slopes at Low, Average, and High Levels of Mean DSS Severity as a Function of Level of Depressive Symptoms

Note. DSS = diabetes-specific stress. Low, average, and high values of mean DSS severity are defined as plus and minus one *SD* about the mean (centered values −0.68, 0, 0.68). Low, average, and high values of depressive symptoms are defined as plus and minus one *SD* about the mean (CES-D raw score values of 4.16, 16.56, and 29.01, respectively). The simple slopes of associations between daily DSS severity and adherence are *not* significantly different from zero for those with low mean DSS severity and average or high depressive symptoms; all other simple slopes are significantly different from zero (see text for simple slope estimates and results of significance tests).

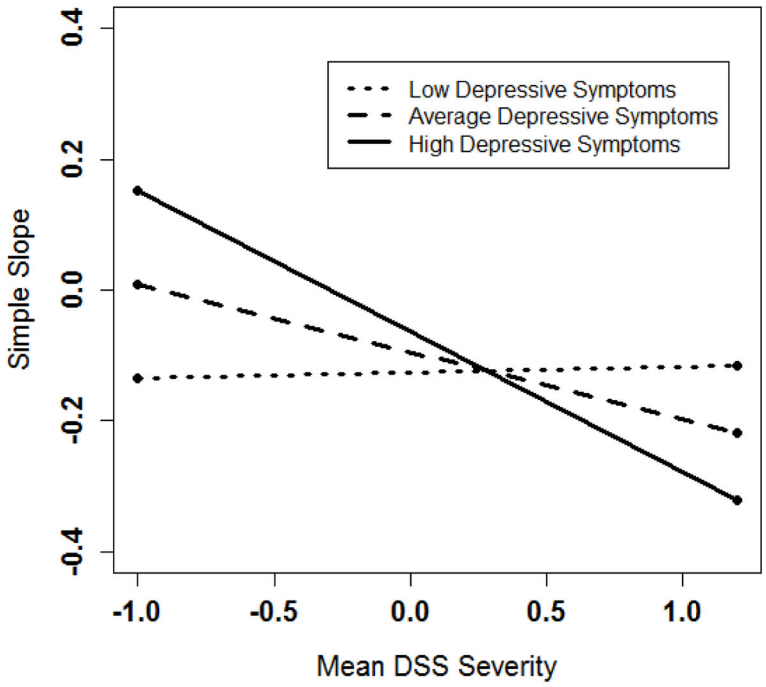

Figure 2. Simple Slopes as a Function of Mean DSS Severity and Level of Depressive Symptoms

Note. Simple slopes of the association between daily DSS severity and adherence. DSS = diabetes-specific stress. Low, average, and high values of depressive symptoms are defined as plus and minus one *SD* about the mean (CES-D raw score values of 4.16, 16.56, and 29.01, respectively). The y-axis represents the association between daily DSS severity and daily adherence and the x-axis the centered value of mean DSS severity (i.e., a slope of 0 suggests no association between daily DSS severity and daily adherence). See text for values of significance region boundaries and associated simple slope estimates.

Table 1

Descriptive Statistics and Correlations among Variables

Variable	*M (SD)*	*1*[a]	*2*	*3*	*4*	*5*
1. Glycemic control[a]	8.19 (1.60)	--				
2. Mean adherence	4.15 (0.68)	−.31***	--			
3. Depressive symptoms	16.56 (12.43)	.27***	−.33***	--		
4. Mean GS severity	2.89 (0.76)	−.01	−.09	.31***	--	
5. Mean DSS severity	2.16 (0.68)	.22**	−.11	.36***	.33***	--

Note. GS = general stress; DSS = diabetes-specific stress. Adherence, GS severity and DSS severity were averaged over days of the daily diary. Possible ranges of scores were: adherence 1–5, depressive symptoms 0–60, GS severity 1–5, DSS severity 1–5.

[a] n = 174 for statistics, correlations including glycemic control.

n = 175.

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 2

Adherence Predicted from Daily Stress Severity, Depressive Symptoms, and Mean Stress Severity

	GS			DSS		
	B	***SE***	***SC***	***B***	***SE***	***SC***
Intercept (γ_{00})	4.18***	0.05		4.16***	0.05	
Depressive symptoms (γ_{01})	−0.02***	0.00	−0.25	−0.02***	0.00	−0.25
Mean stress severity (γ_{02})	0.01	0.08	0.01	−0.03	0.08	−0.02
Gender (γ_{03})	−0.13	0.09	−0.08	−0.12	0.10	−0.07
Depressive symptoms X Mean stress (γ_{04})	−0.01	0.01	−0.07	−0.01	0.01	−0.10
Daily stress severity (γ_{10})	−0.01	0.02	−0.01	−0.10***	0.02	−0.08
Depressive symptoms (γ_{11})	0.00	0.00	0.01	0.00	0.00	0.03
Mean stress severity (γ_{12})	−0.03	0.03	−0.02	−0.10**	0.03	−0.05
Gender (γ_{13})	0.03	0.04	0.01	0.06	0.04	0.02
Depressive symptoms X Mean stress (γ_{14})	0.00	0.00	0.00	−0.01**	0.00	−0.06

Note. GS = general stress; DSS = diabetes-specific stress; SC = standardized regression coefficient (calculated as unstandardized coefficient times *SD* of predictor over *SD* of outcome), which represents the expected change in adherence given a 1 *SD* increase in predictor. See text for results of tests of simple effects.

* $p < .05$,

** $p < .01$,

*** $p < .001$

Health Psychol. Author manuscript; available in PMC 2016 May 01.