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Self-Control, Daily Negative Affect and Blood Glucose Control in Adolescents with Type 1 Diabetes

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Abstract

Objective—For adolescents with type 1 diabetes, maintaining optimal daily blood glucose control is a complex self-regulatory process that likely requires self-control. This study examined whether higher self-control was associated with lower daily negative affect about diabetes and, in turn, better daily blood glucose control, i.e., lower mean daily blood glucose (MBG) and smaller standard deviations of daily blood glucose (SDBG), through two paths: 1) self-control maintaining lower mean level of negative affect and 2) self-control buffering the association of the number of daily diabetes problems with daily negative affect.

Methods—Adolescents (*M* age=12.87 years) with type 1 diabetes (n=180) completed an initial survey containing a self-report measure of self-control. Nightly electronic diaries were completed for 14 days where adolescents reported daily problems with and negative affect about diabetes, and used a study-provided blood glucose meter.

Results—Hypotheses were examined through multilevel modeling. Lower mean levels of daily negative affect partially mediated the relation between higher adolescent self-control and lower

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[1]To address the possibility that frequency of daily blood glucose testing influenced the MBG or SDBG value and results, the same models were also examined weighted by the number of daily blood glucose tests for each participant and the presented findings were replicated.

[2]The interaction utilizing a metric of number of daily problems with diabetes that did not include problems with high or low blood glucose levels was also examined. The results followed a similar pattern with regards to the interaction with self-control (γ_{71}= -.04, SE= .02, p = .07) and main effects of daily problems with diabetes on daily negative affect (M_PR, γ_{022}= .34, SE= .05, p < .001; PROB, γ_{70}= .26, SE= .09, p = .002). The interaction did not remain significant, which may suggest that adolescent management of problems with high or low blood glucose levels may be particularly important for understanding the association of self-control with daily negative affect.

MBG. Adolescent self-control also buffered the association of the number of daily problems with daily negative affect, and smaller fluctuations in daily negative affect were associated with lower SDBG.

Conclusions—Adolescent self-control is associated with daily affect regulatory processes that may influence MBG. However, fluctuations in daily negative affect about diabetes may represent a unique within-person daily process associated with SDBG. These findings suggest that studies examining daily disease processes and interventions targeting daily affect regulation may be important to improving health in adolescents with type 1 diabetes.

Keywords

Type 1 Diabetes; Adolescence; Self-Regulation; Daily Processes

For adolescents with type 1 diabetes, maintaining optimal daily blood glucose control, (i.e., tight diabetes control), is a complex daily self-regulatory process (Lansing & Berg, 2014) that requires the completion of multiple daily adherence behaviors, such as daily blood glucose checks and insulin dosing (Hoffman, 2002). Adolescents must also effectively respond to daily problems that occur while managing diabetes (e.g., high blood glucose readings or miscalculating insulin boluses), and the negative emotions these problems may elicit (Berg et al., 2013; Jaser et al., 2012). This daily self-regulatory process required for optimal daily blood glucose control is likely facilitated by adolescent self-control, the capacity to modulate cognitions, emotions, and behaviors towards a goal (Tangney, Baumeister, & Boone, 2004). Higher adolescent self-control is associated with better blood glucose control over the preceding two to three months (Hughes, Berg, & Wiebe, 2012) and with greater completion of adherence behaviors both over the preceding week or month, and on a daily basis (Berg et al., 2014). However, the associations of self-control with daily blood glucose control in adolescence, and in particular the daily processes linking self-control and blood glucose control, have received limited exploration. In this study, the association of higher adolescent self-control with daily blood glucose control through daily negative affect about diabetes was explored, with a goal to increase understanding of the daily self-regulatory processes that are associated with self-control and daily blood glucose control.

Optimal daily blood glucose control requires that adolescents tightly maintain mean daily blood glucose levels within a healthy range (i.e., between 70 and 180 mg/dl) and limit large variability in blood glucose across the day (Bragd et al., 2008; Kilpatrick, Rigby, Goode, & Atkin, 2007). This is a challenging regulatory task for adolescents, as daily blood glucose levels can vary widely due to diet and exercise, physiological processes such as stress or pubertal maturation, and problems that occur with adherence behaviors as well as associated negative affect that accompanies these problems (Silverstein et al., 2005). Also, adolescents with the same mean blood glucose on a given day may show different levels of variability in blood glucose across the day. For example, some adolescents may keep their blood glucose level tightly around 120 mg/dl throughout the day, while others may have the same average, 120 mg/dl, but with very high and very low blood glucose levels throughout the day. Maintaining tight diabetes control, including both healthy mean daily blood glucose and smaller variability in blood glucose across the day is associated with better long-term health (Bragd et al., 2008; Hirsch & Brownlee, 2010).

Such optimal daily blood glucose control may be facilitated by adolescents' higher self-control. In adolescents without diabetes, self-control is associated with both daily and long-term physical and psychosocial health (Moffitt et al., 2011; Repetti, Taylor, & Seeman, 2002; Silk, Steinberg, & Morris, 2003; Tangney et al., 2004). Higher self-control is associated with better emotion regulation, physiologic recovery from stress, dietary habits, and physical health, both daily and over-time, as well as academic achievement, interpersonal success, and fewer behavioral and emotional problems (Blair & Diamond, 2008; Duckworth & Seligman, 2005; Finkenauer, Engels, & Baumeister, 2005). Daily blood glucose levels in those with type 1 diabetes are interrelated with similar daily behavioral, social-emotional, and physiological processes (Silverstein et al., 2005). For example, both self-control and daily blood glucose levels have been associated with daily affect regulatory processes (Fortenberry et al., 2009; Silk et al., 2003). Thus, in adolescents with type 1 diabetes better self-control may be associated with more optimal daily blood glucose control, and affect regulatory processes might be one mechanism through which that association occurs.

Specifically, self-control may facilitate lower daily negative affect about diabetes and, in turn, more optimal daily blood glucose through two pathways. First, self-control may be associated with lower interindividual levels of negative affect, i.e., lower average negative affect across days. In healthy adolescents, higher self-control is associated with lower interindividual levels of negative affect and it was theorized a similar relation would exist in adolescents with type 1 diabetes (Daly, Baumeister, Delaney, & Maclachlan, 2012; Oldehinkel, Hartman, Ferdinand, Verhulst, & Ormel, 2007; Silk et al., 2003). Second, at an intraindividual level, self-control may also buffer the association of daily problems with diabetes with daily negative affect about diabetes. It is common for adolescents to experience daily problems with diabetes (Berg et al., 2013; Hoffman, 2002) and these types of negative events are likely coupled with changes in negative affect (Larson, Moneta, Richards, & Wilson, 2002; Mroczek & Almeida, 2004). When individuals without diabetes experience problems the extent to which they also experience increases in negative affect is moderated by trait features of the individual, including self-control (Larson et al., 2002; Oldehinkel et al., 2007). An adolescent with type 1 diabetes who is high in self-control may report smaller increases in negative affect after encountering a problem with diabetes management (e.g., high blood glucose reading) than an adolescent low in self-control. Through both pathways, healthier daily negative affect may then be associated with more optimal daily blood glucose control (Fortenberry et al., 2009).

In the present study, daily diary methods were utilized to examine how individual differences in self-control were associated with the daily regulatory process through which adolescents achieved more optimal daily blood glucose control. It was expected that the association of higher self-control with more optimal daily blood glucose control would be mediated by both an indirect effect through lower interindividual negative affect across days, as well as through a moderating effect where higher self-control would be associated with smaller increases in negative affect about diabetes on days when an adolescent experienced problems with diabetes.

Methods

Participants

The data for this study came from an existing database of adolescents with type 1 diabetes (ADAPT, see Berg et al., 2009). The relevant Institutional Review Boards approved the study. Parents gave written informed consent and adolescents gave written assent. The participants were recruited from a university outpatient diabetes clinic and a second clinic conducted by a pediatric endocrinologist following similar treatment guidelines. At initial recruitment in wave 1, eligibility criteria included adolescent age between 10 and 14 years, diabetes diagnosis for more than 1 year, and parent and child ability to read and write either English or Spanish.

The sample for the present study included a portion of adolescents participating in the second wave of the 2.5-year longitudinal study, six months after enrollment. In this wave, 207 of the 252 participants completed diary data. However, 27 adolescents did not provide usable daily blood glucose readings and were dropped from the analyses. Reasons for not providing blood glucose readings included blood glucose meter not returned ($n = 6$), experimenter failure to issue a meter ($n = 6$), software malfunction ($n = 5$), declined the use of our meter or failed to provide readings from their own meter ($n = 8$), and unknown ($n = 2$). These 27 participants did not differ from the remaining 180 on measures of negative affect, self-control, and glycemic control (p's $> .05$). Thus, the final sample included 180 adolescents (*M* Age= 12.87 years, *SD* =1.53, 54% females) diagnosed with type 1 diabetes mellitus for an average of 4.45 years (SD= 2.89), who completed all necessary measures for this study. The mean HbA1c for this sample was 8.45%. Approximately half (57%) of adolescents were on an insulin pump, with the remainder prescribed multiple daily injections (MDI). Families were largely Caucasian (95%) and middle class, with the majority (65%) reporting household incomes averaging $50,000 or more annually.

Procedure

Participants completed assent, and parents consent, at the diabetes clinics, and then participants individually completed the self-control measure in a take-home packet prior to a laboratory appointment. Adolescents were instructed to complete home-questionnaires separately without their parents. A cover sheet reiterated the importance of completing the questionnaires individually and asked that questions be directed to the investigators rather than family members. During a laboratory appointment, participants then completed the adherence measure and were trained in completing the diary and in the use of an experimenter-provided blood glucose meter, which they used during the diary procedure and later returned. Diaries were completed online via a secure website at the end of each day. Trained research assistants checked that online entries were completed and made reminder calls if the entry was not posted by 9 pm. Participants were paid $4 for each completed diary and $50 for completing the packet and training session.

Individual Difference Measures

Self-Control—Adolescents completed a self-control scale that consisted of 11-items designed to tap aspects of the ability to regulate emotions, behaviors, and impulses (Finkenauer et al., 2005). The scale is a shortened version of a 36-item scale created by Tangney, Baumeister, and Boone (2004), but distinct from their Brief Self-Control Scale. Adolescents rated statements about self-control (e.g. “I wish I had more self-discipline”) on a 5-point scale (1= Not at all like me to 5= Very much like me). Finkenauer, et al. (2005) reported adequate reliability, (α = .67); in the present study reliability was good (α = .75).

Other outcome measures—Individual difference measures of adherence and glycemic control were included to clarify associations with the daily measures. *Adherence* to the diabetes regimen over the preceding month was assessed (1 = never to 5 = always did this as recommended without fail) using a 16-item Self Care Inventory (Berg et al., 2008), adapted from La Greca et al., (1995). Items were adapted to reflect current standards of diabetes care around blood glucose testing and insulin management (e.g. “Calculating insulin doses based on carbohydrate content of meals or snacks?”). The scale had excellent reliability in this sample (α = .83). *Glycemic control* was assessed using glycosylated hemoglobin percentages (HbA1c) obtained from the child's routine clinic visit. HbA1c provides information on average blood glucose levels over the preceding three or four months. Lower HbA1c levels reflect better glycemic control. HbA1c was obtained using the Bayer DCA2000 by clinic staff. Participant and parent authorization provided access to medical records to obtain HbA1c and other illness information (e.g. duration of diabetes, pump treatment, etc.).

Daily Diary Measures

The daily diary protocol included a 14 consecutive day diary completed nightly. From the final sample of 180 participants, 5 participants were excluded for completing fewer than 3 days of diary data. Multilevel models used with diary data allow for this level of missing data without biasing results (Raudenbush & Bryk, 2002). Of the 175 participants included in the analyses, 82 completed all 14 days of the diary protocol and an additional 89 participants completed 11 to 13 days of the diary. On average 12.81 diary days were completed.

Daily negative affect about diabetes—Adolescents rated their daily mood on the following eight negative affect items: anxious, sad, annoyed, mad, depressed, nervous, irritated and angry at the end of each day for 14 days. Participants rated on a 1 (slightly) to 5 (extremely) scale “How much did you feel each of the following feelings and emotions related to your diabetes in the past 24 hours?” This measure was adapted from the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) to address emotions typically experienced by adolescents in relation to their diabetes and has been validated in an adolescent sample (Fortenberry et al., 2009). *Daily negative affect* was the average of the items each day. The reliability among the negative affect items across diary days was 0.95. The intraclass correlation of daily negative affect across all 14 days of the diary was 0.63, suggesting that this data contained both interindividual, i.e., between person, (63%) and intraindividual, i.e., within person, (37%) variability in daily negative affect about diabetes.

Number of daily problems with diabetes—Each night in the diary adolescents indicated whether they experienced any of 10 problematic aspects of daily diabetes management on that day. These items were drawn from the most commonly generated problems mentioned by adolescents and mothers in our prior studies (Beveridge, Berg, Wiebe, & Palmer, 2006). Example problems include forgetting or skipping a blood-sugar test, problems eating what you want to, and highs and lows in blood sugar (see Berg et al., 2013 for complete list). A total number of problems per day was calculated. Adolescents reported an average of 1.35 problems per day (*SD* = 1.03, range 0–5.6). The intraclass correlation of daily problems with diabetes across all 14 days of the diary was 0.55, suggesting that this data contains both interindividual (55%) and intraindividual (45%) variability in the number of daily problems with diabetes.

Daily Blood Glucose Control

Across the 14 days of the daily diary, adolescents monitored blood glucose using a meter provided by researchers, resulting in date- and time-stamped records. Adolescents completed on average 4.34 blood glucose tests per day (SD = 1.88, range = 1 to 22 readings). Blood glucose data were screened for outliers and errors in measurement. Two dimensions of blood glucose control were assessed: mean daily blood glucose and blood glucose variability across the day.

Mean daily blood glucose (MBG)—MBG was calculated by averaging across the adolescent's glucose meter readings each day. A very small percentage of the adolescents experienced low blood glucose levels (i.e., less than 2% of the levels were below 80 mg/dl). Thus, when interpreting MBG, higher readings are interpreted as indicating less optimal blood glucose control. The intraclass correlation of MBG across all 14 days of the diary was 0.43 indicating that much of the variance was intraindividual.

Standard Deviation of Daily Blood Glucose (SDBG)—SDBG is a metric of daily blood glucose management that captures variability in blood glucose (i.e., the extent to which adolescents avoid glycemic excursions and tightly maintain their blood glucose levels around their own daily average). SDBG was calculated from the blood glucose data gathered from the participant's meters across the 14 days of the diary. For each day a standard deviation value was calculated to represent variability in blood glucose values across the day. The intraclass correlation of SDBG across all 14 days of the diary was 0.19 indicating that the vast majority of variance was intraindividual.

Analysis Plan

Multilevel model analyses, conducted through Mplus V. 7.2 (Muthen & Muthen, 1998-2012), were utilized to allow for use of daily diary data and simultaneous estimation of inter- and intraindividual effects. Separate variables were calculated to represent the interindividual and intraindividual effects of the daily diary measures. Specifically, interindividual variability in daily negative affect about diabetes, *Mean Negative Affect*, and in daily problems with diabetes, *Mean Daily Problems,* were calculated as each participant's average on that scale across all 14 diary days. Intraindividual variability in daily negative affect about diabetes, *Fluctuations in Daily Negative Affect,* and in daily problems with diabetes, *Fluctuations in Number of Daily Problems with Diabetes,* were each calculated by subtracting a person's mean score on that scale from their score for each diary day. To deconflate the inter- and intraindividual variability, the mean variable was entered simultaneously with the fluctuation variable in any analysis that included daily negative affect or problems with diabetes. Mean negative affect, mean daily problems, self-control, and the covariates time since diagnosis and age were grand mean centered.

When examining daily negative affect as a mediator of the relation between self-control and daily blood glucose control, *mean negative affect* was used as the mediator, as self-control is an individual difference measure and can thus only predict interindividual variance. In contrast, when examining self-control as a moderator of the relation between the number of daily problems with diabetes and predicted levels of daily negative affect, the daily negative affect outcome contains both inter- and intraindividual variance. Given that the negative affect variables in each analysis are not analogous, these two pathways of the model were analyzed separately (Bauer, Preacher, & Gill, 2006; Zhang, Zyphur, & Preacher, 2009). Covariates in each analysis included pump status, age, and time since diagnosis due to their associations with glycemic control (Palmer et al., 2004) and the day the measure was completed.

For the first pathway, mediation models were conducted to examine whether mean negative affect mediated the relation of self-control and daily blood glucose control. Mediation was assessed utilizing methods comparable to those in single-level regression (Krull & MacKinnon, 2001; Zhang et al., 2009). The four equations tested for each mediation model were as follows, using MBG as an example. Equation 1 tested the association of self-control (SC) with blood glucose when controlling for pump status (P), age (A), time since diagnosis (T), diary day (DAY):

$$\begin{array}{ll}\text{LEVEL 1:} & MBG_{ij}=\beta_{0i}+\beta_{1i}(DAY_{ij})+r_{ij}\\ \text{LEVEL 2:} & \beta_{0i}=\gamma_{00}+\gamma_{01}(P_j)+\gamma_{02}(A_j)+\gamma_{03}(T_j)+\gamma_{04}(SC_j)+u_{0j}\end{array} \quad (1)$$

Equation 2 tested the association of daily negative affect, including mean negative affect (M_NA) and fluctuations in daily negative affect (NA) with blood glucose:

$$\begin{array}{ll}\text{LEVEL 1:} & MBG_{ij}=\beta_{0i}+\beta_{2i}(DAY_{ij})+\beta_{3i}(NA_{ij})+r_{ij}\\ \text{LEVEL 2:} & \beta_{0i}=\gamma_{00}+\gamma_{05}(P_j)+\gamma_{06}(A_j)+\gamma_{07}(T_j)+\gamma_{08}(M\_NA_j)+u_{0j}\\ & \beta_{3i}=\gamma_{30}+u_{3j}\end{array} \quad (2)$$

Equation 3 tested the association of the predictor, self-control, with mean negative affect, and Equation 4 tested the association of both the predictor and the mediator with blood glucose.

$$\text{LEVEL 2:} \quad M\_NA_j = \gamma_{00} + \gamma_{09}(P_j) + \gamma_{010}(A_j) + \gamma_{011}(T_j) + \gamma_{012}(SC_j) + u_{0j} \qquad (3)$$

$$\begin{array}{ll} \text{LEVEL 1:} & MBG_{ij} = \beta_{0i} + \beta_{4i}(DAY_{ij}) + \beta_{5i}(NA_{ij}) + r_{ij} \\ \text{LEVEL 2:} & \beta_{0i} = \gamma_{00} + \gamma_{013}(P_j) + \gamma_{014}(A_j) + \gamma_{015}(T_j) + \gamma_{016}(SC_j) + \gamma_{017}(M\_NA_j) + u_{0j} \\ & \beta_{5i} = \gamma_{50} + u_{5j} \end{array} \qquad (4)$$

Equations 3 and 4 were tested simultaneously in Mplus, which allowed for estimation of a confidence interval for the indirect effect of self-control on blood glucose through mean negative affect. The indirect effect of self-control on blood glucose through mean negative affect was calculated as the product of $\gamma_{012}(SC_j)$ from Equation 3 and $\gamma_{017}(M\_NA_j)$ from Equation 4. Monte Carlo confidence intervals were utilized to assess the significance of the indirect effects.

For the second pathway, self-control was hypothesized to moderate the association of fluctuations in the number of daily problems with diabetes and the level of daily negative affect about diabetes. The equation for this moderation model was as follows:

$$\begin{array}{ll} \text{LEVEL 1:} & \text{NegativeAffect}_{ij} = \beta_{0i} + \beta_{6i}(DAY_{ij}) + \beta_{7i}(\text{PROB}_{ij}) + r_{ij} \\ \text{LEVEL 2:} & \beta_{0i} = \gamma_{00} + \gamma_{018}(P_j) + \gamma_{019}(A_j) + \gamma_{020}(T_j) + \gamma_{021}(SC_j) + \gamma_{022}(M\_PR_j) + u_{0j} \\ & \beta_{7i} = \gamma_{70} + \gamma_{71}(SC_j) + u_{7j} \end{array} \qquad (5)$$

The association of the interaction between fluctuations in the number of daily problems and self-control with the level of daily negative affect was represented by $\gamma_{71}(SC_j)$.

Results

Table 1 presents descriptive data on each measure and Pearson correlations among key study variables. Correlations were examined among self-control, and mean levels (i.e., averaged across all 14 days of the diary) of negative affect, problems with diabetes, blood glucose and SBDG, as well as adherence and glycemic control. Individuals with higher self-control were more likely to report lower mean negative affect, fewer mean problems, lower mean MBG and smaller mean SDBG across the 14 day diary period. Mean MBG and mean SDBG were positively correlated with each other and with HbA1c, and negatively correlated with adherence. Mean SDBG was not significantly associated with mean negative affect or mean problems with diabetes.

Daily Negative Affect about Diabetes as a Mediator of the Link Between Self-Control and Daily Blood Glucose Control

To test the hypothesis that mean negative affect would mediate the association of self-control with daily blood glucose control, sets of analogous mediation models were conducted predicting MBG and SDBG. The initial conditions (equations 1 and 2) for mediation were established in the data. Consistent with hypotheses, higher adolescent self-control was associated with both lower MBG and SDBG (see Table 2). For every 1-point increase in self-control, MBG was lower by 28.18 mg/dl and SDBG was smaller by 7.59 mg/dl. Second, both mean level of negative affect as well as fluctuations in daily negative affect predicted MBG and SDBG (see Table 2). These findings indicate that for every 1 point decrease in mean negative affect, MBG was lower by 31.5 mg/dl and SDBG was smaller by 7.4 mg/dl, and for every 1 point decrease in fluctuations in daily negative affect MBG was lower by 14.1 mg/dl and SDBG was smaller by 8.8 mg/dl.

Equation 3 and 4 were then analyzed to test if the model was consistent with mediation for both MBG and SDBG outcomes (see Figure 1). For MBG, the findings were consistent with partial mediation, where mean negative affect partially mediated the relation of self-control with MBG (indirect effect = -9.67, Z= -2.43, p = .02, 95% Monte Carlo CI = -18.87 to -3.13). Adolescent self-control (γ_{016} = -19.40, SE= 7.57, p = .01) and fluctuations in daily negative affect (γ_{60} = 14.14, SE= 4.60, p = .002) continued to predict variance in MBG uniquely from mean negative affect ((γ_{017} = 23.96, SE= 6.99, p = .001). Also, pump status (γ_{013}= 16.91, SE= 8.17, p = .04) remained a significant predictor of MBG in this model. Significant variance in MBG remained with all predictors in the model (γ_{00} = 177.00, SE= 11.74, p < .001, variance = 2305.10, p < .001). However, there was not significant interindividual variability in the strength of the relation between MBG and fluctuations in daily negative affect (variance = 1163.81, p = .07), suggesting this relation was consistent across persons.

For the SDBG the findings were not consistent with mediation. Mean negative affect did not mediate the relation of self-control with SDBG (indirect effect = -2.15, Z= -1.39, p = .17, 95% Monte Carlo CI = -5.82 to 0.44). In fact, adolescent self-control (γ_{016}= -5.33, SE= 3.34, p = .11) and mean negative affect (γ_{017}= 5.34, SE= 3.33, p = .11) did not maintain significant associations with SDBG. Fluctuations in daily negative affect did significantly predict SDBG (γ_{60} = 8.79, SE= *2.50,* p < .001). Also, adolescent age (γ_{014}= -3.27, SE= 1.21, p = .01) and time since diagnosis (γ_{015} = 1.73, SE= .67, p = .01) remained significant predictors of SDBG. Significant variance in SDBG remained with all predictors in the model (γ_{00}= 86.75, SE= 6.46, p < .001, variance = 457.73, p < .001). However, there was not significant interindividual variability in the relation between SDBG and fluctuations in daily negative affect (variance = 65.85, p = .38) suggesting this relation did not vary across persons.

These models indicate that mean negative affect partially mediated the relation between self-control and MBG, while only fluctuations in daily negative affect were significantly associated with SDBG[1]. Specifically, adolescents with higher self-control reported lower negative affect across days than those with poorer self-control, and this in turn partially explained the association with lower MBG. Adolescents with smaller fluctuations in daily negative affect experienced lower variability in blood glucose across the day measured via SDBG.

Self-Control Moderating the Link Between Daily Problems with Diabetes and Daily Negative Affect about Diabetes

Next, we examined the hypothesis that self-control would moderate the link between fluctuations in the number of daily problems with diabetes and daily negative affect about diabetes (equation 5). Supporting the hypothesis, self-control moderated the association of fluctuations in the number of daily problems with diabetes and the level of daily negative affect (γ_{71}= -.04, SE= .02, p = .04)[2]. This interaction is depicted in Figure 2, where adolescents who were high in self-control did not experience as large of an increase in negative affect on days in which they experienced a greater number of problems with diabetes than usual. Simple slopes analyses (Bauer & Curran, 2005) indicated that adolescents who were lower in self-control had a steeper slope between fluctuations in the number daily problems with diabetes and daily negative affect (γ= .12, p < .001) than adolescents higher in self-control (γ= .06, p < .001).

Further, in this moderation model, there was a main effect of self-control on daily negative affect (γ_{021}= -.32, SE= .09, p < .001). There were also main effects of mean problems with diabetes (M_PR, γ_{022}= .23, SE= .05, p < .001) and fluctuations in the number of daily problems with diabetes (PROB, γ_{70}= .09, SE= *.01*, p < .001) on daily negative affect. Significant variance in the slope between fluctuations in the number of daily problems and daily negative affect remained (variance = .01, p = .002) that was not accounted for by the effect of self-control. Last, there was a linear association between the day the diary was completed and daily negative affect (β_{6i} = -.01, SE= .003, p < .001). Regardless of self-control skill or number of daily problems with diabetes, participants reported slightly less negative affect each day as the diary progressed across the two weeks. None of the other covariates in this model (i.e., pump status, age, and time since diagnosis) were significantly associated with daily negative affect.

Overall, these results suggested that adolescent self-control buffered the association of having more problems than usual with diabetes and higher negative affect about diabetes.

Discussion

This study explored the association of higher self-control with more optimal daily blood glucose control in adolescents with type 1 diabetes. Higher self-control was associated with both lower mean daily blood glucose and smaller variability in blood glucose across the day. These results supported the argument that self-control is part of a foundation of self-regulatory skills that are necessary for successful daily diabetes management (Berg et a1., 2014; Lansing & Berg, 2014). Two daily affect regulatory pathways were hypothesized to mediate that association and subsequently examined. First, adolescents with higher self-control were more likely to experience lower mean negative affect across days, which in part explained lower mean daily blood glucose levels. Second, adolescents higher in self-control did not experience higher levels of negative affect on days in which they experienced more problems with their diabetes than usual. Better adolescent self-control was associated with daily diabetes management through interindividual differences in negative affect and perhaps a mechanism of limiting affect-related disruptions to daily blood glucose control. These results are consistent with findings that self-control facilitates effective daily self-regulation, including affect regulation, allowing individuals to engage in healthier behaviors and experience better psychosocial health (Blair & Diamond, 2008; Daly et al., 2012; Repetti et al., 2002; Silk et al., 2003).

It is important to note that intraindividual fluctuations in negative affect were associated with variability in daily blood glucose levels above and beyond both of the interindividual processes discussed thus far, self-control and mean negative affect. This suggests that even adolescents who are higher in self-control and experiencing lower levels of negative affect across days may have larger variability in blood glucose levels on days where they experience greater fluctuations in negative affect. This is consistent with burgeoning research on glycemic variability and emotional functioning in individuals with diabetes (Rausch, 2010). Also, this finding highlights the importance of considering and conducting analyses that do not confound inter- and intraindividual variability in daily processes. Research on intraindividual variability, especially related to daily affect, suggests that often inter-and intraindividual processes may differentially explain psychosocial and physiological outcomes (Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2004; Watson, 1988).

Thus, research on adolescents with diabetes and their families may benefit from greater consideration of both inter- and intraindividual processes that may be related to disease management and health outcomes. For example, research suggests that there is also intraindividual variability in self-control in adolescents with type 1 diabetes (see Berg et al., 2014) making it possible that daily variability in self-control may explain daily variability in affect and blood glucose levels. Intraindividual variability in self-control should be explored in conjunction with understanding interindividual self-control and affect (Hofman, Baumeister, Forster, & Vohs, 2012). Future research examining both inter- and intraindividual self-regulation and daily blood glucose control may be helpful in understanding the individual, family, and biological processes associated with both self-regulation and daily blood glucose control, as well as long-term complications of type 1 diabetes.

The conclusions drawn from this study must be considered in the context of some limitations. This study relied on cross-sectional, same day data. Longitudinal studies of the associations examined in this study would help to determine if there are changes over time in the self-regulatory processes that influence daily blood glucose control. Also, the use of mother or teacher reports, as well as behavioral measures of self-control, would clarify the importance of adolescent perceptions of self-control vs. more objective metrics of adolescent self-control. This sample included primarily Caucasian, middle class families and our findings may not generalize to a more diverse or lower income sample. Another limitation is that the measures of daily negative affect and daily problems with diabetes were completed at the end of each day, while blood glucose readings were taken throughout the day. Use of these methods limited the exploration of moment-to-moment changes in negative affect and blood glucose levels in response to experiencing problems with diabetes management. Research on daily disease management processes would benefit from the utilization of both ecological momentary assessment and continuous glucose monitoring that capture moment-to-moment changes that occur in self-control, affect, and blood glucose control. Finally, the daily blood glucose data relied on adolescent testing of blood glucose levels. Other studies indicate that such methods may provide incomplete data on daily blood glucose control, in particular with regards to the variability of daily blood glucose (Monnier et al., 2007). Studies examining these phenomena utilizing continuous blood glucose monitors would provide more complete data on daily blood glucose.

Important clinical implications can be drawn from the findings of this study. This research suggests that it would be beneficial for psychosocial interventions to target adolescents' daily responses to problems with diabetes towards preventing increases in daily negative affect that may disrupt daily blood glucose control. Such interventions may be especially useful for adolescents who have poorer capacity for self-control. Interventions that target affect regulation, such as cognitive behavioral and coping skills interventions for children and adolescents, may be helpful (Wyman et al., 2010). Many interventions for adolescents with type 1 diabetes, such as Grey's Coping Skills intervention (Grey, Boland, Davidson, Li, & Tamborlane, 2000) or Wysocki's Behavioral Family Systems intervention (Wysocki et al., 2008), already address affect regulation and problem-solving skills, and may be adapted to increase emphasis on daily responses to problems. If limiting variability in blood glucose levels across the day is a target of the affect regulation intervention, the treatment may be useful for individuals with both high and low levels of self-control. Finally, mobile intervention methods that enable scaffolding (i.e., support that is decreased over time to facilitate an independent skill) of adaptive responses to problems during the day may be particularly useful in modifying the daily processes through which adolescents self-regulate to achieve optimal blood glucose control (Mulvaney, Anders, Smith, & Pittel, 2012).

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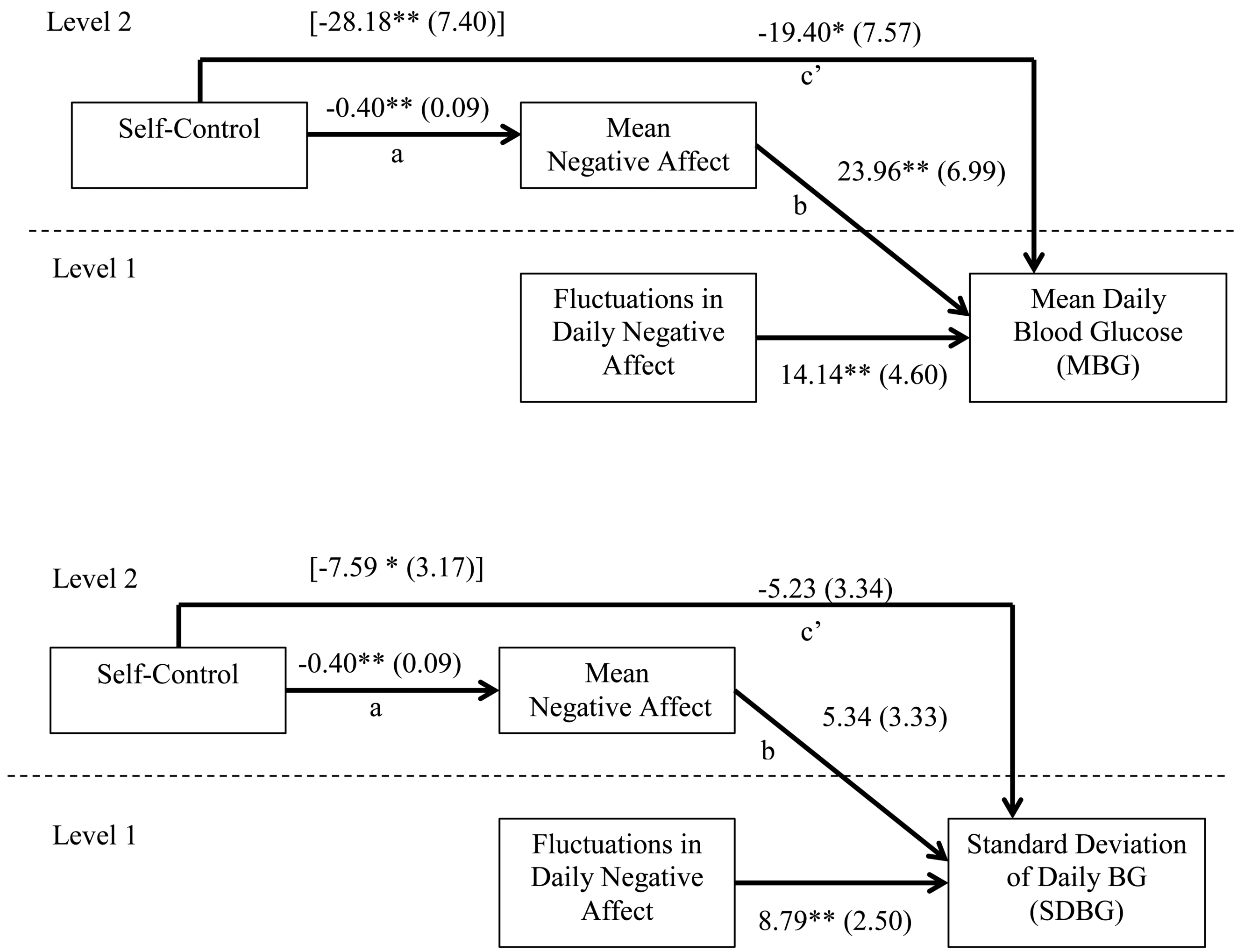

Figure 1. Mean Negative Affect Mediates the Relation Between Self-Control and MBG, while Fluctuations in Daily Negative Affect Predict SDBG

Note: The bracketed coefficient on the c′ pathway is the coefficient from equation 1, where only self-control was predicting daily blood glucose. All other coefficients are from the final equation 3, with all variables in the model predicting the outcome. Covariates included in these models are discussed in the text and not included here to reduce complexity in the figures.

$^{*}p < .05$; $^{**}p < .01$

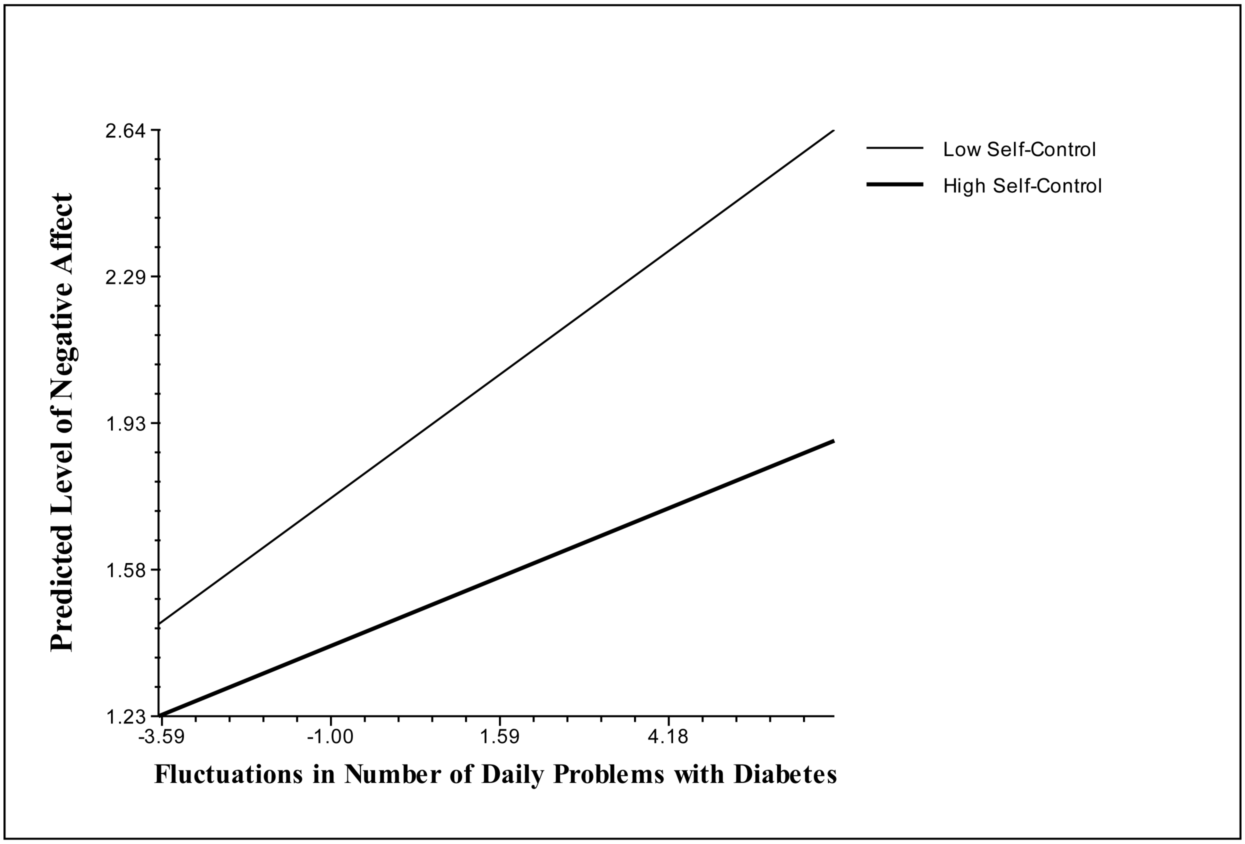

Figure 2. Self-Control Moderates the Association Between Fluctuations in the Number of Daily Problems with Diabetes and Daily Negative Affect

Table 1

Correlations, Means and Standard Deviations

	M_NA	M_PROB	M_MBG	M_SDBG	ADH	HbA1C	Mean (SD)
Self-Control (SC)	-.39**	-.22**	-.33**	-.20**	.28**	-.30**	3.53 (0.64)
Negative Affect ^ (M_NA)		.44**	.33**	.14	-.15	.22**	1.65 (0.78)
Number of Problems with Diabetes ^ (M_PROB)			.16*	.15	-.31**	.22**	1.43 (1.52)
Mean Daily BG ^ (M_MBG)				.74**	-.30**	.64**	201.36 (78.52)
Standard Deviation of BG ^ (M_SDBG)					-.24**	.46**	93.78 (52.58)
Adherence (ADH)						-.20**	3.90 (0.53)
HbA1c							8.45 (1.54)

^ Mean level for the sample during the two week diary period.

Table 2

Self-control and Daily Negative Affect predict Mean Daily Blood Glucose and the Standard Deviation of Daily Blood Glucose

Variable	*b*	SE	t	Variance
Self-Control Predicting MBG				
Intercept	181.83	11.78	15.43**	2462.30**
Intraindividual (Level 1)				
Day	0.28	0.39	0.71	
Interindividual (Level 2)				
Pump Status (P)	15.35	8.22	1.87	
Age (A)	-3.53	2.83	-1.25	
Time Since Diagnosis (T)	0.61	1.38	0.44	
Self-Control (SC)	-28.18	7.40	-3.81**	
Self-Control Predicting SDBG				
Intercept	88.65	6.35	13.97**	475.51**
Intraindividual				
Day	0.08	0.28	0.28	
Interindividual				
Pump Status (P)	4.44	4.18	1.06	
Age (A)	-3.31	1.27	-2.61**	
Time Since Diagnosis (T)	1.73	0.69	2.52*	
Self-Control (SC)	-7.59	3.17	-2.40*	
Daily Negative Affect Predicting MBG				
Intercept	172.24	11.86	14.52**	2417.08**
Intraindividual				
Day	0.63	0.40	1.59	
Fluctuations in Daily Negative Affect (NA)	14.09	4.57	3.08**	1096.42
Interindividual				
Pump Status (P)	19.75	8.58	2.30*	
Age (A)	-2.79	2.70	-1.02	
Time Since Diagnosis (T)	0.53	1.33	0.40	
Mean Negative Affect (M_NA)	31.52	7.21	4.37**	
Daily Negative Affect Predicting SDBG				
Intercept	85.57	6.31	13.56**	462.71**
Intraindividual				
Day	0.14	0.30	0.47	
Fluctuations in Daily Negative Affect (NA)	8.79	2.52	3.49**	70.06
Interindividual				
Pump Status (P)	5.81	4.21	1.38	

Variable	*b*	SE	t	Variance
Age (A)	-3.02	1.22	-2.48 *	
Time Since Diagnosis (T)	1.68	0.68	2.48 *	
Mean Negative Affect (M_NA)	7.41	3.22	2.30 *	

* $p < .05$;

** $p < .01$

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