Ecological Momentary Assessment of Anxiety, Daily Stress, and Daily Glycemic Control in Adolescents with Type 1 Diabetes

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ECOLOGICAL MOMENTARY ASSESSMENT OF ANXIETY, DAILY STRESS, AND DAILY GLYCEMIC CONTROL IN ADOLESCENTS WITH TYPE 1 DIABETES

by

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ABSTRACT
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Type 1 diabetes (T1D) is an increasingly common chronic illness in children and adolescents that can result in short- and long-term health complications. Adolescents with T1D represent a uniquely vulnerable population, as both physical and psychological disease outcomes tend to deteriorate during this period of development. Thus, among adolescents it is crucial to gain further understanding of what psychological and contextual factors promote optimal disease management. While traditional methods of assessment in this population involve one-time, long-term measurements of psychosocial factors and glycemic control, ecological momentary assessment (EMA), including daily diaries, are increasingly used to capture change processes both between and within individuals. The present study utilized EMA methods (daily diaries for seven days) to explore associations between general stress (GS), diabetes-specific stress (DSS), and glycemic control. Anxiety was measured at baseline and examined as a moderator.

Forty-four adolescents (ages 13-17) diagnosed with T1D were recruited from diabetes summer camps. Participants completed the Revised Children's Manifest Anxiety Scale, 2nd Edition at camp. Daily diaries, including measures of GS and DSS, were completed in the fall. Participants uploaded blood glucose values via Tidepool®, which were used to calculate daily mean blood glucose values. Daily GS and DSS scores were used to quantify both within- and between-subjects variance in each construct.

Multilevel model analyses revealed that increased within-subjects fluctuations in daily DSS were predictive of poorer daily glycemic control. Conversely, between-subjects variation in average levels of DSS across the measurement period did not play a significant role in predicting mean daily blood glucose. GS levels were not predictive of glycemic control at either level. Additionally, trait anxiety did not moderate the association of fluctuations in daily DSS with glycemic control.

Overall, the association between fluctuations in daily diabetes-specific stress and same-day glycemic control highlights the need for clinicians to focus on bolstering adolescents' adaptive responses to daily disease-related stressors. Additionally, this study underscores the importance of examining both between- and within-person psychosocial processes in individuals with T1D in order to fully understand the mechanisms underlying disease management.

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Introduction

Type 1 diabetes (T1D) is one of the most prevalent chronic illnesses in the United States. Currently, 1.25 million individuals are living with T1D, including an estimated 200,000 children and adolescents (Centers for Disease Control and Prevention, 2017). With up to 18,000 new cases in youth annually, it is expected that by the year 2050 up to 600,000 children and adolescents will be living with the disease (Dabelea et al., 2014). An autoimmune disease, T1D results when pancreatic cell destruction leads to insulin deficiency, resulting in an inability to convert food and glucose into energy (Daneman, 2006). Because T1D is most often diagnosed in childhood or young adulthood, the disease poses many inherent challenges to youth and their caregivers, including constant disease monitoring and an often invasive treatment regimen. Poor disease management may have serious short- and long-term consequences for physical health. Adolescents represent a uniquely vulnerable population, as both physical and psychological disease outcomes tend to deteriorate during this period of development (Garvey et al., 2012; Hilliard et al., 2013). Additionally, adolescence is often the time when youth begin to assume more responsibility for their own disease management, and they form habits that are likely to carry into adulthood. Thus, among adolescents it is crucial to gain further understanding of what psychological and contextual factors promote optimal disease management.

There are many psychological factors whose associations with disease management and glycemic control are well established in pediatric diabetes literature. The emotional burden of living with and managing a chronic illness daily may lead to internalizing symptoms, particularly depression. A wealth of existing research shows

higher levels of psychological distress in adolescents with T1D when compared to their healthy peers; additionally, increases in depressive symptoms are linked with poorer glycemic control in teens with T1D (Buchberger et al., 2016; Hood et al., 2006). A meta-analysis of studies examining psychological distress among children and adolescents with T1D as compared to their healthy peers revealed that those with T1D report significantly higher levels of depressive symptoms, a higher frequency of clinical depression, more anxiety, and more general psychological distress than the control group (Reynolds & Helgeson, 2011). Health-related quality of life is poorer for youth with T1D, and it also tends to deteriorate in adolescence (Graue et al., 2003). Stress may also negatively affect adolescents' ability to manage their disease. In addition to the general stress experienced by healthy adolescents, youth with T1D experience diabetes-specific stressors that are related to poor glycemic control (Helgeson et al., 2010). Optimal glycemic control requires adolescents (and their caregivers) to adhere to a strict health regimen and to successfully carry out a variety of regulatory tasks every day, which can cause stress specifically related to completing out these tasks.

Historically, the study of psychosocial factors in the context of pediatric diabetes has relied on one-time recall measurements. This approach, while logistically simple, conflicts somewhat with psychologists' interest in youths' everyday, real-world behavior. Ecological momentary assessment (EMA) refers to a range of assessment methods that are naturalistic, ambulatory, and real-time (Heron et al., 2017). These methods have many methodological advantages, including reduced recall errors and bias and increased ecological validity (Smyth & Heron, 2014). EMA is particularly relevant to research examining glycemic control and related factors in children and adolescents with T1D

given the potential for daily fluctuations in individual characteristics and diabetes management demands.

The present study will utilize EMA methods to examine relationships between daily stress and daily blood glucose levels and the potential moderating role of anxiety. Following a summary of basic information about T1D in adolescents, literature pertaining to anxiety and stress in this population will be reviewed. The paper will then describe existing research employing EMA methods with youth with T1D before discussing the goals and approach of the present study.

The following terms will be used throughout this paper and must therefore be defined. “Glycemic control” refers to typical levels of blood glucose in an individual and is often used as a proxy for how well-controlled one’s diabetes is. “Adherence” or “treatment adherence,” sometimes also referred to as “compliance,” will be used to describe the degree to which youth follow typical medical advice for the management of T1D (American Diabetes Association, 2020). Although the terms are sometimes conflated in T1D research, it is important to note that “adherence” is a behavioral construct while “glycemic control” refers to the physiological outcome. In this study, glycemic control will be utilized as an objective physiological indicator of disease management, with lower values corresponding to more successful management.

Type 1 Diabetes Management

For youth and adults with T1D, disease management involves an intensive treatment regimen that often requires individuals to fit their lifestyle to their illness. To compensate for the fact that the pancreas does not produce insulin, individuals with T1D must monitor their blood glucose (BG) levels and administer insulin appropriately.

Medical professionals encourage individuals with T1D to aim for BG levels similar to those of healthy individuals. Glycemic control reflects the extent to which individuals accomplish this, with lower numbers reflecting better control. Target BG levels for children and adolescents vary slightly by age but generally range from 90 to 150 mg/dl (American Diabetes Association, 2020). BG levels have traditionally been monitored with multiple daily finger pricks. Continuous glucose monitors (CGMs), introduced in 2005, provide a glucose level once every five minutes, resulting in infinitely more data than one receives from finger prick checks four to six times per day. The use of CGMs in adolescents with T1D can significantly improve their glycemic control by providing accurate data, promoting patient communication with medical providers, and enhancing motivation to self-monitor blood glucose levels (Bergenstal et al., 2010; Schaepelynck-Belicar et al., 2003). Recent data from the Type 1 Diabetes Exchange Registry suggest that 17% of adolescents nationwide use a CGM, a number that increased significantly between 2011 and 2016 (DeSalvo et al., 2018). Current recommendations include considering CGM use for all children and adolescents with T1D (American Diabetes Association, 2020).

Long-term glycemic control is measured with hemoglobin A_{1C} (HbA_{1C}), which is an objective measure reflecting one's average BG level over the past two to three months (Gonder-Frederick & Cox, 1991). Values are expressed as percentages of hemoglobin that is glycated (i.e., bonded to glucose). Recommendations from the American Diabetes Association for target HbA_{1C} levels are presented by age group, such that adolescents are expected to meet similar requirements to adults (American Diabetes Association, 2020). Achieving lower HbA_{1C} levels, while ideal, also creates more frequent risk for

hypoglycemia. Young children may also be less able to recognize physiological symptoms of hypoglycemia; hence, children under 6 years of age have a target HbA_{1C} value of 7.5% to 8.0%. Adolescents are told to aim for a value under 7.5% given the higher risk of poor glycemic control leading to complications post-puberty.

Physiological Complications of T1D

Poor glycemic control can have severe short- and long-term consequences for individuals with T1D. Without (and sometimes even with) close daily attention to BG levels and insulin administration, inconsistent out-of-range BG levels can lead to short-term physiological symptoms and above-target HbA_{1C} levels in the long term. In the moment, low BG levels can cause immediate symptoms including shakiness, sweating, irritability, confusion, rapid heartbeat, dizziness, hunger, and weakness (American Diabetes Association, 2020). High BG levels can lead to thirst, frequent urination, headaches, nausea, and diabetic ketoacidosis, which is a life-threatening condition in which the body breaks down fat and muscle for energy due to a lack of available insulin (Wolfsdorf et al., 2006). Long-term complications of T1D typically result from chronically high BG levels, as symptoms of hyperglycemia are easier to ignore or habituate to. Immediate symptoms of low BG are disruptive and often incapacitating; thus, hypoglycemia is often treated immediately. That said, extremely low BG levels can result in seizures and loss of consciousness, especially in children and other individuals unable to recognize early symptoms of hypoglycemia. T1D reduces the typical lifespan by 11 to 13 years and significantly increases the risk of heart disease and stroke (Livingstone et al., 2015). Kidney damage is a common long-term complication and leads to complete kidney failure over time in approximately 30% of patients with T1D

(National Kidney Foundation, 2015). Neuropathy in the feet and other extremities is also common. T1D is the leading cause of both blindness and lower limb amputations in the U.S. every year (American Diabetes Association, 2020).

T1D in Adolescence

In addition to the many inherent management challenges of T1D at any age, adolescents must also grapple with developmental challenges that occur during this period. Adolescence is a pivotal time for T1D management, especially as caregiver involvement tends to decrease and adolescents take on increasing responsibility (Hanna & Guthrie, 2003). Adolescence is a period of rapid biological development and increasing emotional, cognitive, and physical maturity that is often characterized by teens' search for autonomy and independence from caregivers (Herzer & Hood, 2010). Moreover, hormonal development can trigger changes in insulin sensitivity related to physical growth and sexual maturation and may also result in a neurological vulnerability to hypoglycemia and hyperglycemia (Barnea-Goraly et al., 2014). More than half of youth with T1D do not meet the glycemic control guidelines prescribed by their endocrinologists (Amed et al., 2013). A wealth of research with adolescents shows steady increases in HbA_{1C} levels throughout adolescence, often plateauing at high levels around the age of 17 and remaining high through young adulthood (e.g., Clements et al., 2016).

During childhood, T1D management tasks are primarily the responsibility of caregivers. During adolescence, this responsibility begins to transfer to the youth in preparation for adulthood. This transition period can be one of the most difficult times for adolescents with T1D (Garvey et al., 2012). Because adolescents are physically able to complete adherence tasks, parents may be tempted to quickly hand all responsibility to

their children. However, while adolescents may be physically prepared for the increased responsibility, they often need help with the decision-making and planning required to execute T1D tasks successfully (Herzer & Hood, 2010). This may leave youth feeling unsupported and vulnerable, which can result in an avoidance of self-care and follow-up care from medical providers. Reduced parental monitoring and poorer communication, together with an increase in time spent outside the home (e.g., more extracurricular activities and less predictable schedules), are often associated with declines in adherence (Amed et al., 2013; Hilliard et al., 2013; Rustad et al., 2013). Conversely, caregivers may be hesitant to relinquish control over daily management tasks. This may result in a frustrating dynamic in which adolescents wish for autonomy that caregivers are unwilling to give. These unpredictable caregiver-adolescent dynamics are often related to poor glycemic control (Anderson et al., 2009).

Of course, it is not the case that adherence and glycemic control decline universally across individuals. A multitude of physiological, psychological, and contextual factors affect adolescents' ability to manage the many adherence tasks involved in maintaining optimal glycemic control. A longitudinal study of over one thousand youth with T1D found that significant deteriorations in glycemic control occurred over the first six years after diagnosis for adolescents. Moreover, psychosocial burden was a specific contributor to these suboptimal glycemic outcomes (Hood et al., 2014). The following section will review research examining specific psychosocial factors that are associated with adherence and glycemic control in adolescents.

Psychosocial Factors Related to Adherence in Adolescents with T1D

Research has documented that a wide variety of psychosocial factors are related to adherence behaviors, and glycemic control by extension, in adolescents with T1D. Some, such as negative mood and affect, have been researched for years; others have been explored only more recently. Before exploring how psychosocial factors fluctuate on a daily basis in this population, it is necessary to thoroughly review the research exploring global relationships between these factors and adolescents' ability to complete management tasks and glycemic control.

Anxiety

Negative mood and affect have long been established as psychological factors with a reliable relationship to both adherence and glycemic control in individuals with T1D. Depression and anxiety both stand out as internalizing syndromes that are prevalent in this population. An early study of youth with diabetes showed that nearly 50% of adolescents were diagnosed with a psychiatric disorder within 10 years of their T1D diagnosis, and chief among them was depression (Kovacs et al., 1997). Hood and colleagues (2006) found that nearly one in seven youth with T1D report clinically significant symptoms of depression, which is nearly double the highest estimates of rates in the general adolescent population. Although specific rates vary between studies based on methods of measurement, an abundance of research has reported concerning rates of internalizing symptoms in adolescents with T1D.

Anxiety is a leading concern in this population. Silverstein and colleagues (2005) reported that over 18% of youth with T1D are diagnosed with an anxiety disorder at some

point during their childhood or adolescence, and a more recent study found that a similar proportion (21.3%) of their sample screened positive for an anxiety disorder (Bernstein et al., 2013). Additionally, relationships between increased anxiety symptoms and poorer adherence and glycemic control are well documented (e.g., Herzer & Hood, 2010). A recent meta-analysis confirmed that a high proportion (i.e., 32%) of adolescents with T1D report symptoms of anxiety, and that these symptoms are associated with poorer glycemic control (Buchberger et al., 2016). Trait (i.e., baseline) anxiety has been associated with increased fear of hypoglycemia, increased rates of hypoglycemia, decreased rates of BG monitoring, and poorer ability to distinguish between physiological symptoms of anxiety and hypoglycemia (Rechenberg, Whittemore, & Grey, 2017).

The directionality of the relationship between anxiety and poor glycemic control is unclear. Some work shows that diabetes-related worries negatively impact adherence and glycemic control (e.g., Mortensen, 2002; Naar-King et al., 2006). Conversely, Gonder-Frederick and colleagues (2006) found that a history of hypoglycemic episodes predicts current diabetes-related stress and anxiety, implying that poor glycemic control in the past impacts current anxiety about diabetes. Thus, it is not clear whether poor glycemic control elicits anxiety or if the opposite is true; the relationship is likely bidirectional. Herzer and Hood (2010) examined the prevalence of internalizing symptoms in adolescents with type 1 diabetes and associations between anxiety and glycemic control in this population. In congruence with prior research, results indicated that adolescents experiencing higher levels of both state and trait anxiety and higher levels of depression checked their BG less frequently per day and had poorer long-term glycemic control. Thus, it is possible that symptoms of anxiety may interfere with

adolescents' ability to complete adherence tasks, negatively impacting glycemic outcomes. Conversely, the daily demands and variable outcomes of T1D disease management may contribute to increase symptoms of anxiety in these youth. However, the specific mechanisms of the relationship between anxiety and glycemic control, and its negative impact on the health of these youth, are poorly understood.

General and Diabetes-Specific Stress

Stress has also been explored as a factor that plays a role in adolescents' glycemic control. Adolescents in the U.S. report general stress at rates equal to or higher than their adult counterparts (American Psychological Association, 2018). Primary stressors in this age group include gun violence, the political climate, money, and health-related concerns. For adolescents with T1D, the disease diagnosis is a significant additional stressor. Helgeson and colleagues (2010) conducted a longitudinal study and found that frequency of stressful life events predicted psychological distress, poorer self-care behavior, and poorer glycemic control. These associations were stronger among older adolescents (e.g., ages 15-17) than younger ones (e.g., ages 11-14).

Not all stress is created equal, especially for individuals with chronic illnesses. The distinction between general stress (GS) and diabetes-specific stress (DSS) is an important one when exploring diabetes-related outcomes such as adherence and glycemic control. Adolescents and parents report frequent problems related to hyperglycemia or hypoglycemia, forgetting to check their BG levels, and leaving supplies at home accidentally (Beveridge et al., 2005; Fortenberry et al., 2012). DSS as a construct thus focuses on stress related to these diabetes-specific problems. This distinction between GS and DSS is an especially important one given past research showing that diabetes-specific

stress is uniquely related to poor diabetes outcomes (Farrell et al., 2004). Chao et al. (2016) explored general and diabetes-related stressors in adolescents with T1D and found that the vast majority of teens reported school as a top stressor, followed by social life, and diabetes. Diabetes stressor themes included having diabetes, dealing with emotions related to diabetes, and diabetes management.

Although Chao and colleagues noted that teens perceived GS more frequently than DSS, related research has shown that DSS is uniquely related to poor glycemic control. Farrell and colleagues (2004) explored both perceived GS and perceived DSS and their respective associations with adherence behaviors and glycemic control (i.e., HbA_{1C}). Results revealed that greater DSS was directly related to higher HbA_{1C} (i.e., poorer glycemic control), while greater GS was only indirectly associated with higher HbA_{1C} via poorer adherence behaviors. Conversely, DSS was not related to adherence behaviors, which led the authors to conclude that GS may be more disruptive to daily routines given that it involves multiple domains of adolescents' lives. Hagger and colleagues (2016) conducted a systematic review of "diabetes distress" in adolescents, which they defined as negative emotions that arise from living with T1D. While this construct likely includes more than just DSS, researchers found that associations between "diabetes distress" and HbA_{1C} were strongest when distress was assessed with the Diabetes Stress Questionnaire (Berlin et al., 2012), which specifically measures DSS. This finding implies a close relationship between DSS and glycemic control.

Additional research has underscored the nuances of DSS experienced by this population and implications for health-related outcomes. Berlin, Rabideau, and Hains (2012) examined patterns of subtypes of perceived DSS among youth with T1D. Three

pattern profiles of perceived DSS emerged including low stress, interpersonal/peer stress, and family stress. The group of adolescents who reported family stress as primary also had significantly higher HbA_{1C} values than adolescents who reported experiencing primarily the other two types of DSS. These results are consistent with what is known about diabetes-specific family conflict and the potential for turmoil during adolescence as responsibility for disease management transitions from caregiver to teen (Williams et al., 2009). This research highlights the fact that global measures of stress may not sufficiently account for associations between perceived stress and glycemic control. Thus, it is important to account for adolescents' perceptions of their diabetes-specific stress and appraisal in order to promote optimal disease management.

Taken together, the results of the studies reviewed here indicate that both anxiety and stress have important, established relationships with adherence and glycemic control in adolescents with T1D. Although in most cases directionality has yet to be established, it is clear that poor psychosocial functioning has negative implications for diabetes management in this population. The majority of the studies reviewed thus far have utilized one-time recall measurements of all variables. While studies using these approaches are crucial to the establishment of global relationships between psychosocial factors and diabetes-related outcomes in this population, the following section will review studies that employ more nuanced, ambulatory approaches to explore these relationships further.

EMA as a Methodology

Behavioral scientists aim to study human behavior, thoughts, and emotions in ways that allow them to draw conclusions about participants' everyday real-world

experiences. However, such behaviors, thoughts, and emotions are most often studied in the context of a lab, hospital, or other artificial setting that bears many distinctions from individuals' typical lives. Such approaches arose out of a desire to control the experiences of participants; however, in doing so, researchers often render findings ungeneralizable to other settings. Furthermore, individual experiences are often studied globally via one-time recall self-reports that ask participants to report on a summarized experience over a long period of time (e.g., level of anxiety over the past six months), which introduces the potential for recall bias (Shiffman et al., 2008). Psychological research often asks participants to summarize their experiences over a period of time (e.g., "how intense was your pain over the past month?"). The longer this period of time, the more participants rely on cognitive heuristics to estimate a response (Margetts et al., 2003). In psychology especially, it is important to focus on short-term reports in order to understand how thoughts, feelings, and behaviors may vary over brief periods of time. Many psychosocial factors undergo dynamic changes from day to day or from moment to moment. Psychological researchers' reliance on one-time recall data fails to consider such real-world, dynamic processes. It is crucial to examine data on a more immediate level in order to better understand the mechanisms underlying global patterns that have been observed.

"Ecological momentary assessment" does not refer to one single method of data collection, but rather to a range of assessment methods that are naturalistic, ambulatory, and real-time (Heron et al., 2017). These methods include daily diaries (both paper/pencil and electronic), experience sampling, and ambulatory monitoring of physiological parameters. EMA as a group of methodologies can be especially helpful in answering

research questions relating to the impact of environmental or situational factors (e.g., comparing adherence behaviors at school and at home); natural day-to-day fluctuations in thoughts, feelings, or behaviors; or the impact of internal factors (e.g., relationships between daily stress and adherence behaviors). EMA emerged fairly early in the history of behavioral research, as many behavioral scientists designed studies asking participants to record information about their subjective experiences (e.g., behaviors, thoughts, emotions, social interactions) over time (Shiffman et al., 2008). EMA was also used early in the field of health psychology as a way of checking the accuracy of health-related self-report data about illness episodes (Thiele et al., 2002).

EMA is an increasingly popular method of data collection in the social and health sciences, including with child and adolescent populations, and it holds many advantages for behavioral researchers. The administration approach allows participants to complete surveys and diaries in a naturalistic setting; often participants complete measures on a home computer or mobile phone, or they are given paper-pencil measures to fill out over the course of a week or month. Researchers using EMA recognize that many behaviors and experiences are influenced by the environment, and thus it is imperative to sample behaviors and experiences in the context in which they typically occur (Shiffman et al., 2008). This increases the ecological validity of collected data.

Unfortunately, all self-reported data is subject to recall biases that threaten their validity. Additionally, recall bias is not evenly distributed; rather, it is systematic in nature. For instance, individuals are more likely to recall negatively-valenced information when they are experiencing negative moods (Hassan, 2005). Furthermore, recall depends on memory, which can be notoriously unreliable in many ways. Details of an event may

not be noticed and therefore not stored in memory. Additionally, memory distorts recall even after relatively short intervals, and repeated retrieval of the same memory may lead to further distortions or additional information being stored (Bradburn et al., 1987). By asking participants to reflect on the past day (or the past few hours), as opposed to a longer period of time, EMA researchers decrease the likelihood of errors in memory. This is especially relevant to psychological research, in which researchers often ask participants to summarize their experiences over a period of time (e.g., "how intense was your pain over the past month?").

The intensive nature of EMA data collection also allows for a reduction of the recall period, which may increase the validity of participants' responses. This advantage is particularly relevant when conducting research with children and adolescents, who may face increased struggles in accurately reporting on behaviors and experiences as compared to adults (Heron et al., 2017). Specific to pediatric populations, youth may be better able to report on subjective experiences of pain and sensation, treatment adherence, sleep, and psychological symptoms across shorter time periods. Lastly, EMA data collection yields intensive longitudinal data, or data with repeated measurements over a relatively short time period, which allow for the examination of within-subject changes in behavior and experience over time and across contexts (Shiffman et al., 2008).

Disadvantages of EMA approaches are few but not insignificant. EMA approaches are inherently time-intensive, as they require the repeated assessment of the same subjects. This challenge highlights the appeal of bringing participants to the lab to complete various one-time measures and is likely a leading reason of why EMA approaches, while more comprehensive, are not a default methodology. Researchers must

determine how best to administer such assessments repeatedly to participants in their homes. Paper diaries, while simple to create, may nevertheless be problematic when participants must report times of day at which they are completing measures. Electronic diaries will record times automatically, which is important given that studies have shown many individuals are not truthful when reporting times of day (Clifford et al., 2014). Electronic diaries, however, are not always financially feasible. Many of the most successful EMA studies involved researchers giving participants phones or small tablets to use over the course of the EMA period, which may come at a significant economic cost. Despite the price, Hufford and Shields (2002) argued for the development and use of electronic diaries, citing poor data quality and suboptimal compliance with paper diaries.

EMA and Type 1 Diabetes

EMA methodologies are particularly relevant to research examining the management of life with T1D. In addition to daily variation in psychosocial factors, youth with T1D experience moment-to-moment fluctuations in their physiology (e.g., blood glucose levels). These fluctuations are likely to be accompanied by physiological symptoms that may interact with psychosocial factors over the course of a day. Additionally, the gold-standard measure of glycemic control, HbA_{1C}, is an oversimplified global measure of a factor that fluctuates daily, even from hour to hour. Using HbA_{1C}, an average of three months' worth of BG values, does not consider daily, weekly, or even monthly variation that is crucial to the understanding and improvement of glycemic control. Additionally, two individuals may have the same HbA_{1C} value over one three-month period but wildly different BG values during that same period; this would have

important implications for potential diabetes-related physiological complications. Unfortunately, HbA_{1C} alone may not be the best predictor of later complications. Analysis of data from the Diabetes Control and Complications Trial revealed that blood glucose variability adds to the risk of microvascular complications from diabetes, above and beyond that predicted by HbA_{1C} value alone (Kilpatrick et al., 2008). Although low BG value will bring down one's average BG level, a low BG value does not counteract the damage done by a high BG value (and may in fact lead to its own complications). Thus, the importance of examining day-to-day adherence and glycemic control is evident.

As has been reviewed in previous sections, there exists a wealth of research establishing relationships between myriad psychosocial factors and glycemic control in adolescents with T1D. However, the literature reviewed thus far has exclusively examined relationships between HbA_{1C} and psychosocial variables as measured by one-time recall assessments. More recently, research has begun to examine how some of these psychosocial variables vary on a daily basis and the relationship between those variations and individuals' daily BG values.

Specifically, 11 studies have been conducted with adolescents with T1D utilizing EMA methods. The studies employed a variety of data collection methods (see Table 1). Across these studies, those with the highest rates of participant compliance were those that utilized once daily online surveys for up to two weeks, provided small incentives for each completed diary, and contacted participants nightly with reminders or problem-solving help. These methods were not only the most successful, but they were the most popular among the 11 EMA studies reviewed here. These methods appear feasible and successful with children and adolescents as young as 10 years old. It is likely that the

flexibility of the once daily online survey leads to such high compliance rates; adolescents may have benefitted from being able to complete surveys at home in the evening, which also provided parents the opportunity to remind them about participation.

Two exemplary studies (i.e., Baucom et al., 2015; Lansing et al., 2016) utilizing EMA methods to great effect in this population explored relationships between daily psychosocial functioning and daily BG levels, in addition to examining the role of baseline trait characteristics (i.e., self-control and depression, respectively). Lansing and colleagues (2016) explored what individual processes link daily self-regulation with daily BG levels and the moderating role of self-control. Participants completed a baseline measures of self-control and adherence, followed by 14 consecutive days of daily diary measures of negative affect about diabetes and number of diabetes problems experienced. During this 14-day period, adolescents monitored their BG levels using meters provided by researchers. Adolescents with higher baseline self-control experienced less negative affect on days when they had many diabetes problems. Higher baseline self-control was also related to lower mean BG values and less BG variability. These results support previous findings that self-control facilitates effective affect regulation and enables better diabetes care, which emphasizes the role of multiple aspects of self-regulation in optimal daily diabetes care.

Given established findings that depressive symptoms are increased in youth with more poorly controlled diabetes, researchers have examined to what extent depressive symptoms might account for poor adherence in the short term, with the presumption that this may be the mechanism contributing to poor long-term glycemic control. Baucom and colleagues (2015) explored relationships between daily stress, depressive symptoms, and

daily adherence in adolescents with T1D and the possible moderating role of depressive symptoms on the relationship between stress severity and daily adherence. Researchers also distinguished between general stress and diabetes-specific stress. Again, participants completed baseline measures, followed by a 14-day diary of both GS and DSS severity and adherence. Not only did this sample report high levels of depressive symptoms, but these depressive symptoms were associated with more severe daily stress, poorer daily adherence, and poorer glycemic control. Adolescents reported poorer adherence on days with more severe DSS, which emphasizes the unique role of specific stress on adolescents' ability to complete adherence tasks each day. Additionally, adolescents high in depressive symptoms and high in DSS showed an association between daily DSS and adherence behaviors. Hence, among adolescents with T1D, the combination of more severe depressive symptoms and high daily DSS may make it particularly challenging to manage one's diabetes.

In summary, researchers have utilized EMA methods and the resulting intensive longitudinal data to establish relationships between daily psychosocial processes and glycemic control in adolescents with T1D. Additionally, researchers in this area have emphasized the value of combining moment-to-moment assessment of psychosocial variables with data from advancing blood glucose monitoring technology (i.e., continuous glucose monitors) in order to examine how within-day fluctuations in psychosocial processes relate to BG values at the same times.

Importantly, no study to date has examined relationships between daily stress, anxiety, and glycemic control in adolescents. Aikens and colleagues (1992) explored relationships between daily GS and HbA_{1C} in adults with T1D and found that individuals

with greater fluctuations in daily GS severity had higher HbA_{1C} levels. It is not currently known if adolescents with T1D exhibit similar daily stress and glycemic control patterns as adults, whether this pattern is the same for both GS and DSS, or whether anxiety plays the same moderating role as does depression in this equation (Baucom et al., 2015). Given the many daily stressors (both general and diabetes-specific) in the lives of adolescents with T1D, it is crucial to explore the psychological and physiological effects of stress on this population and furthermore to determine the characteristics of youth who are most susceptible to daily fluctuations in stress.

Present Study Overview and Hypotheses

Given the nature of T1D management and the possibility for daily fluctuations in emotions, stressors, and diabetes-related outcomes, the current study examined relationships among stress and glycemic control on a daily level and the potential moderating role of trait-level (i.e., baseline) anxiety. This study measured participants' anxiety at baseline and utilized EMA methods to measure daily fluctuations in general and diabetes-specific stress. Additionally, BG data for the same period was collected in order to evaluate relationships between the psychosocial factors listed above and individuals' daily glycemic control. Daily BG data were averaged to create a mean blood glucose (MBG) value for each day of the EMA period, which was used as a measure of daily glycemic control. Aims and hypotheses for the present study included the following:

Aim 1: To explore between- and within-person associations between daily stress (i.e., general and diabetes-specific) and daily glycemic control among adolescents with T1D.

Hypotheses:

1a. Adolescents will exhibit higher MBG levels on days when DSS fluctuates to a greater level than their respective averages.

1b. Adolescents who report higher mean levels of DSS across days will exhibit higher MBG levels across days.

1c. Adolescents will exhibit higher MBG levels on days when GS fluctuates to a greater level than their respective averages.

1d. Adolescents who report higher mean levels of GS across days will exhibit higher MBG levels across days.

Aim 2: To examine whether between-person differences in baseline anxiety levels moderate each of these associations.

Hypotheses:

2a. Adolescents who report higher levels of baseline anxiety will experience larger increases in MBG on days when they report higher DSS than their average DSS, as compared to adolescents who report lower levels of baseline anxiety.

2b. Adolescents who report higher levels of baseline anxiety will display a stronger positive association between overall DSS and MBG than adolescents who report lower levels of baseline anxiety.

2c. Adolescents who report higher levels of baseline anxiety will experience larger increases in MBG on days when they report higher GS than their average GS, as compared to adolescents who report lower levels of baseline anxiety.

2d. Adolescents who report higher levels of baseline anxiety will display a stronger positive association between overall GS and MBG than adolescents who report lower levels of baseline anxiety.

Research Design and Method

Participants

Participants in this study included 44 adolescents aged 13 to 17 years with a current diagnosis of type 1 diabetes for more than one year. Potential participants with a diagnosis of type 2 diabetes were excluded from the study. Adolescents who participated in a pilot version of this study in previous summers were eligible for recruitment. *A priori* power analyses indicated that 42 subjects would be necessary in order to have 80% power to detect a medium effect size for all hypothesized direct effects at .05 criterion of statistical significance.

A total of 79 participants from two field sites were recruited for this study and completed baseline measures: 52 from the California site and 27 from the Nevada site. Participants from each site were compared on demographic variables (e.g., age at testing, age at diagnosis, race/ethnicity), pump status, CGM status, and RCMAS-2 score. Participants from the California site were older than those from the Nevada site, $t(77) = 3.23$, $p = .002$. No other significant group differences were observed.

Forty-four of the 79 recruited participants completed some or all of the daily surveys. Participants who completed daily surveys were compared to those who did not on demographic variables, pump status, CGM status, and RCMAS-2 score. Subjects who used a CGM were more likely to complete daily surveys than those who do not use a CGM, $\chi^2 = 7.289$, $p = .007$. No other significant group differences were observed. There were no significant differences in daily survey completion between the two sites, $\chi^2 = 1.06$, $p = .30$. Five participants completed one daily survey, two completed two surveys,

one completed three surveys, two completed four surveys, two completed five surveys, and 32 completed all seven surveys.

Of the 44 participants who completed daily surveys, 25 uploaded BG data to Tidepool®. Participants who completed uploads were compared to those who did not on demographic variables, pump status, CGM status, RCMAS-2 score, and mean GS and DSS severity. Girls were significantly more likely than boys to complete an upload, $\chi^2 = 6.68$, $p = .01$. No other significant group differences were observed.

Procedure

Participants were recruited from diabetes camps located in California and Nevada in the summer of 2019. Parents of children who were registered for camps hosted by the Nevada Diabetes Association and Diabetes Youth Families were emailed information by the camp directors about the study and the investigators prior to the start of camp. Families interested in participating completed online parent permission forms. In-person recruitment also took place immediately before the start of each camp.

Adolescents whose parents gave permission for their participation gave written assent before proceeding with study procedures. For each stage of data collection they completed, participants were entered to win one of three $25 gift cards.

Following individual assent, participants completed an initial survey of baseline anxiety on an iPad (Stage 1). Following camp, participants were contacted and asked to complete seven daily surveys assessing general and diabetes-specific stress (Stage 2). This occurred in the fall when participants had returned to school and other typical activities in order to increase the ecological validity of the data. Participants were intentionally asked to participate after their first week back at school in order to capture a

representative school week. Weeks with school holidays (e.g., Labor Day) were also avoided when possible. The survey period began on Monday and ended on Sunday. Surveys were sent each day via email or text message to either the participant or their caregiver, depending on participant preference. Daily reminders were sent to participants if they had not completed the survey by an agreed-upon time of day. After this period of daily diary completion, participants were asked to upload their BG data (Stage 3), which included BG data concurrent with the daily survey period. BG data were uploaded via Tidepool®, which is an open-source, FDA-approved website that allows researchers to access patient data.

Measures

Revised Children's Manifest Anxiety Scale – Second Edition (RCMAS-2)

The RCMAS-2 (Reynolds & Richmond, 2008) is a 49-item self-report measure of anxious thoughts, feelings, and behaviors (see Appendix A). Questions are presented in a simple yes/no format, and adolescents typically spend 10 minutes or less completing the measure. Individual item scores are used to calculate a total anxiety score in addition to subscales scores of physiological anxiety, worry, and social anxiety. Subscale scores were determined by a factor analysis of the full reference sample of 3,086 U.S. children and adolescents (Reynolds & Richmond, 2008).

The RCMAS-2 (and previous versions of the measure) have been used to assess anxiety in adolescents with T1D (Helgeson & Novak, 2006; Kamps et al., 2005) and adolescents with various chronic illnesses (Houck et al., 2006). A meta-analysis of anxiety in children with chronic illnesses found that ratings of anxiety using the RCMAS

in this population were similar to those on other well-validated measures (e.g., Behavior Assessment System for Children, State-Trait Anxiety Inventory for Children; Pinquart & Shen, 2011). In the current sample, internal consistency for the full scale as measured by Cronbach's alpha was good ($\alpha = 0.87$). In the present study, total anxiety score T-scores (mean score of 50, standard deviation of 10) were used for analyses.

Demographics

Adolescents were asked to report on date of birth, diabetes diagnostic status, age of diagnosis, gender, grade in school, race, ethnicity, and pump/CGM status (see Appendix B). Demographic variables were collected to describe the sample and were used to assess for potential group differences.

Daily General Stress (GS)

Participants completed a checklist of five daily events related to general stress (i.e., argument or disagreement with someone, problem with school or schoolwork, problem with work or chores, having to deal with other people's problems, and problem related to where they live or things they own; see Appendix C). These items were adapted by Baucom and colleagues (2015) from the Daily Inventory of Stressful events (Almeida et al., 2002). Participants indicated whether they experienced each stressful event that day and how stressful each endorsed event was on a scale of 1 (*not stressful at all*) to 5 (*as stressful as it can get*). For each event endorsed, adolescents also indicated whether it was related to their diabetes. This was rarely the case for these general stress events: argument or disagreement with someone (18.8%), problem with school or schoolwork (15.8%), problem with work or chores (40.0%), having to deal with other people's problems

(4.3%), problem related to where they live or things they own (40.0%), broadly consistent with previous research utilizing this measure (Baucom et al., 2015). Overall, 18.2% of general stress events were related to diabetes. Daily general stress (GS) severity was calculated by taking the sum of the ratings across general stressors endorsed, divided by the number of total items (i.e., five). Thus, items that were not experienced were accounted for with a rating of zero. No prior reliability information is available for this measure. Previous research using this scale has revealed relationships between daily GS and depressive symptoms (Baucom et al., 2015).

Daily Diabetes-Specific Stress (DSS)

Participants completed a checklist of five daily events related to diabetes-specific stress (i.e., problem with high/low blood sugar, forgetting or skipping a BG test, taking the wrong amount of insulin, feeling bad because of diabetes, and problem with pump or CGM; see Appendix C). These items were developed by Baucom and colleagues (2015) from coding of open-ended descriptions of mother- and adolescent-reported diabetes events (Beveridge et al., 2005). Participants indicated whether they experienced each stressful event that day and how stressful each endorsed event was on a scale of 1 (*not stressful at all*) to 5 (*as stressful as it can get*; Baucom et al., 2015). Daily diabetes-specific stress (DSS) was calculated by taking the sum of the ratings across diabetes stressors divided by the number of total items (i.e., 5). Thus, items that were not experienced were accounted for with a rating of zero. No reliability information is available for this measure. Previous research using this scale has revealed relationships between daily DSS, glycemic control, and depressive symptoms (Baucom et al., 2015).

Daily Glycemic Control

Participants were asked to report their daily BG values. Previous studies comparing self-reported BG values with meter downloads have found no significant differences between values (Herzer & Hood, 2010; McGrady et al., 2009), and self-reported BG values have been solely used in past EMA studies with this population (e.g., C. A. Berg et al., 2014). BG data collected varied depending on participants' technology and device usage. Participants who check their BG values with meters were asked to report all BG values for the given day, in addition to corresponding time stamps. Participants who use a CGM were asked to report their BG levels for the current day at the following times: 6:00 am, 9:00 am, 12:00 pm, 3:00 pm, 6:00 pm, and 9:00 pm (if applicable). Daily BG values were averaged to generate daily mean blood glucose (MBG) values and daily standard deviation of blood glucose values (SDBG).

Blood Glucose Data Uploads

Participants were asked to upload blood glucose data (from a meter or a CGM) for the seven days for which they completed daily diaries to a secure website using Tidepool®. Information about devices used by each participant was gathered at recruitment. Private accounts were created for each participant that could only be accessed by the research team. Participants were sent instructions specific to their devices and were provided with technical support as needed.

Preliminary Analyses

Multilevel model analyses, conducted through SPSS v.25.0, were utilized to allow for use of intensive longitudinal data and simultaneous consideration of between- and

within-subjects effects. Missing data were accounted for using full information maximum likelihood. Therefore, all data points (i.e., individual daily surveys) were included in the dataset regardless of how many of the seven daily surveys each participant had completed. Separate variables were calculated to quantify between- and within-subjects variance of daily diary predictor variables. Specifically, mean GS and DSS severity were calculated as each participant's average score on each respective scale across all seven diary days. These values were also grand mean centered. Within-subjects variance in GS and DSS severity (i.e., daily fluctuations in GS and DSS severity) were calculated by subtracting each participants' mean score on that scale from their score for each diary day (i.e., person centering). For any analysis that included GS or DSS severity, both mean severity and daily fluctuations in severity were entered simultaneously in order to account for both types of variance separately. In all models, time (i.e., day 1, day 2, day 3, etc.) was accounted for but was not a significant predictor.

BG data were used to create two BG-related outcome variables: mean BG values (MBG) were calculated by averaging participants' BG levels each day; standard deviation of BG (SDBG) was calculated as the standard deviation of participants' BG levels each day. These daily outcome variables were entered into models as single, non-transformed variables that contain both between- and within-subjects variance. Gender, age at diagnosis, and pump status were considered as covariates given that these variables have known associations with glycemic control (Palmer et al., 2004). There was minimal variability in the pump status variable (i.e., 93% of the sample reported using a pump) and thus the decision was made to exclude it from further analyses. Gender and age at diagnosis were entered into all models as covariates.

To examine between- versus within-subjects variance in daily diary measures, intraclass correlation coefficients (ICCs) were calculated for DSS and GS severity, MBG values, and SDBG values across the measurement period. ICCs indicated that 44% of the variation in DSS severity, 33% of the variation in GS severity, 56% of the variation in MBG, and 42% of variation in SDBG was between-subjects.

Blood Glucose Values

In the final sample of 44 participants, 25 (56.8%) completed BG data uploads via Tidepool®. All participants provided self-report BG values. In order to explore the accuracy of self-reported BG values, these values were compared to Tidepool® BG values for participants who provided BG data uploads (n = 25). Self-reported BG values were separated into between- and within-subjects variance and regressed onto Tidepool BG values (both MBG and SDBG, respectively). Results indicated that, for MBG, the model was significant, $F(2, 157) = 113.63$, $p < .001$, and both average self-reported MBG across the week, $B = 0.91$, $SE = .07$, $p < .001$, and fluctuations in self-reported MBG, $B = 0.59$, $SE = .07$, $p < .001$, were associated with Tidepool® MBG. Similarly, for SDBG, the model was significant, $F(2, 156) = 37.97$, $p < .001$, and both average self-reported SDBG across the week, $B = 0.85$, $SE = .13$, $p < .001$, and fluctuations in self-reported SDBG, $B = 0.38$, $SE = .06$, $p < .001$, were associated with Tidepool® SDBG. Thus, it was concluded that self-reported BG data in this sample were reasonably accurate. For all main analyses reported here, Tidepool® BG data were used when available (n = 25) due to their objectivity and increased accuracy, and self-reported BG data were used for all other participants (n = 19). Notably, all models presented in the Results section were also

run using a) only Tidepool® data for those who had it, and b) only self-report data for all participants, and the same pattern of results was found in all cases.

Pilot Testing

Pilot testing for the present study was conducted in order to assess feasibility of the current data collection method. Fifty participants between the ages of 11 and 17 were recruited from Nevada camps. All participants completed baseline measures at camp. Two months later, all 50 participants were contacted for follow-up. Twenty-nine (58%) responded and agreed to complete five days of EMA measures. Daily reminders were sent as described in the procedure section above. Over the five-day period, 28 participants completed at least one daily diary. Following the EMA period, those 28 participants were asked to upload BG data. Six participants completed the upload. No incentives were offered for any stage of data collection.

Results of pilot testing suggest that adolescents and their parents are generally willing to enroll in studies with no offer of incentives and complete baseline measures at the time of recruitment. However, motivation to complete later stages of data collection may have decreased as time passed from recruitment. Thus, in the present study, incentives were offered after each stage in order to increase the likelihood that participants will complete all stages of data collection. The EMA period was lengthened from five to seven days, and nightly reminders were again sent to participants and/or their parents.

Results

Tables 3 and 4 present descriptive statistics for key study variables and correlations among these variables. Bivariate correlations were conducted between mean levels of DSS severity, GS severity, MBG, and SDBG values (i.e., averaged across the seven-day measurement period) and RCMAS scores. Adolescents with higher mean DSS severity were also more likely to report higher mean GS severity. Mean MBG and mean SDBG were positively correlated.

Average anxiety symptom scores in the present study were below the suggested clinical cutoff (i.e., T-score of 60), but 25% of the present sample (n = 11) scored in the subclinical or clinically significant range. This finding is broadly consistent with prior research indicating relatively high levels of trait anxiety in adolescents with T1D as compared to their health peers (Buchberger et al., 2016). Adolescents who reported higher anxiety at baseline also experienced higher average levels of DSS severity across the measurement period.

Relationships Between Diabetes-Specific and General Stress Severity and Mean Blood Glucose

Multilevel models were conducted to test the first hypotheses that higher levels of DSS and GS severity would be related to higher MBG values. Results of all models can be found in Table 5. Increased within-subjects fluctuations in daily DSS severity were associated with higher daily MBG values. Results indicated that for every 1-point increase in diabetes-specific stress severity, MBG was higher by 9.44 mg/dl. Conversely, between-subjects differences in average DSS levels across the measurement period were not associated with daily MBG values. Similarly, neither within-subjects fluctuations in

daily GS severity nor between-subjects differences in average GS levels were associated with daily MBG values. Thus, Hypothesis 1a was supported, but Hypotheses 1b, 1c, and 1d were not.

Anxiety as a Moderator of the Relationship Between Fluctuations in Daily Diabetes-Specific Stress Severity and Mean Blood Glucose

Given the null results of Hypotheses 1b, 1c, and 1d, only hypothesis 2a was tested. To test the hypothesis that trait anxiety would moderate the association of fluctuations in DSS severity with MBG, a moderation model was conducted predicting MBG. Inconsistent with the hypothesis, trait anxiety did not moderate the relation of within-subjects fluctuations in daily DSS severity with daily MBG. Individuals' levels of trait anxiety did not affect the slope of the relationship between fluctuations in daily DSS severity and daily MBG levels.

Exploratory Analyses

Although hypotheses focused on the ability of psychosocial variables to predict daily mean blood glucose values (MBG), exploratory analyses were conducted to examine relationships between key study variables and standard deviations of daily blood glucose values (SDBG) given existing research demonstrating that BG variability is a clinically significant health outcome (Hoffman et al., 2016). Multilevel models were conducted to test the associations between DSS and GS severity and SDBG. No significant associations were found between daily SDBG values and within-subjects fluctuations in daily DSS severity, between-subjects differences in average DSS levels, within-subjects fluctuations in daily GS severity, or between-subjects differences in average GS levels. As with MBG, moderation models were run to test the potential

moderating role of trait anxiety on relationships between stress and SDBG, and none were found to be significant.

Additionally, multilevel models were conducted to explore the potential additive effects of fluctuations in both DSS and GS severity on blood glucose levels. There is some research to suggest that the combination of increases in DSS and GS together might impact BG outcomes more than either independently (Rechenberg, Whittemore, Holland, et al., 2017). However, the interaction between fluctuations in DSS and GS severity did not have a significant impact on daily MBG levels or on daily SDBG levels.

Discussion

The present study explored relationships between daily stress (both general and diabetes-specific), daily blood glucose levels, and trait anxiety in adolescents with T1D. Ecological momentary assessment, a relatively new approach to research with adolescents, was utilized to gather data that allowed for the examination of both between- and within-subjects processes. This study was also innovative in its use of objective measures of daily glycemic control (i.e., data uploaded from glucometers or continuous glucose monitors), and it was the first to explore the potential moderating role of anxiety symptoms on the relationship between stress severity and daily glycemic control.

Results indicated that within-subjects fluctuations in daily diabetes-specific stress (DSS) were predictive of daily glycemic control (i.e., mean daily blood glucose levels). By contrast, between-subjects differences in average levels of DSS across the measurement period did not play a significant role in predicting mean daily blood glucose. This suggests that on days when DSS levels are higher than an individual's own typical level, glycemic control suffers as a result. However, individuals' respective

average levels of DSS do not differentiate their glycemic control. This result highlights the importance of individual stress management by demonstrating that intraindividual variability in stress is associated with poorer glycemic control. These findings also underscore the subjectivity of perceived stress and the extent to which stress is the result of one's personal interpretation of a situation and subjective psychosocial conditions (Lindfors et al., 2017; Schraml et al., 2011). This subjectivity may further explain why between-subjects differences in average levels of both diabetes-specific and general stress did not differentiate glycemic control in this sample. However, DSS is distinguished from GS in predicting glycemic control because at the individual level, atypically high DSS severity on a given day predisposes adolescents to higher BG levels. Notably, the directionality of this relationship is unclear. It is possible that high levels of DSS impede good diabetes management by decreasing adolescents' ability to complete daily adherence tasks and thereby worsen glycemic control. It may also be that high blood glucose levels on a particular day trigger an increase in DSS severity, especially for those adolescents who are attentive to their BG levels and attempt to maintain good glycemic control.

Contrary to hypotheses, GS severity was not predictive of daily MBG at either level of variance. Neither average levels of GS across the measurement period nor daily fluctuations in GS were related to glycemic control. Existing research on the distinction between GS and DSS is mixed, and the role of each in predicting diabetes outcomes is unclear. In accordance with the present findings, Baucom and colleagues (2015) found that GS severity was not related to daily adherence behaviors or glycemic control (as quantified by HbA_{1C}), while DSS severity was. Rechenberg and colleagues (2017) also

examined both types of stress and found that while GS and DSS were each independently related to diabetes outcomes, when both types of stress were entered into the same model, GS no longer contributed significantly to glycemic control. However, GS did maintain its contribution to adherence behaviors. Similarly, Farrell and colleagues (2004) found that daily GS severity was only associated with glycemic control via adherence behaviors. Importantly, the present study examined only glycemic control as an objective outcome and not adherence behaviors. Thus, based on these and prior findings, it may be that GS plays a role in management behaviors but does not directly impact glycemic control. For example, experiencing high levels of GS severity may direct adolescents' attention away from completing adherence tasks throughout the day, while resulting glycemic control (i.e., BG levels) is more likely to directly impact (or be impacted by) DSS severity. Notably, in the present study, average DSS levels across the sample were higher than those of GS, which is in contrast to some other studies that have found GS more prevalent in adolescents (Chao et al., 2016). This may be related to the timing of our study; most of the daily diary data were collected early in the fall, when participants may have been experiencing relatively low levels of school- and peer-related stress. By contrast, diabetes-specific stressors (e.g., taking the wrong amount of insulin, forgetting to check BG levels) are constantly present for these adolescents.

Interestingly, no significant relationships were found between DSS or GS severity and SDBG. While it is known that glycemic variability (such as SDBG) is related to significant health outcomes for individuals with T1D (e.g., inflammation and microvascular complications; Gorst et al., 2015; Hoffman et al., 2016), fewer studies have examined relationships between SDBG and psychosocial outcomes. Notably, SDBG

may be a better indicator of individuals' daily experiences of hyper- and hypoglycemia than of overall glycemic control and, by extension, chronic diabetes complications. However, long-term glycemic variability is known as a potential barrier to achieving optimal glycemic control (McCall & Kovatchev, 2009). It is also important to consider the fact that participants in this study reported very high rates of diabetes technology use compared to the general pediatric diabetes population (Miller et al., 2015). This may have resulted in relatively low levels of glycemic variability over the measurement period, which could explain the lack of findings regarding SDBG. It is possible that in a sample with increased glycemic variability, relationships between DSS and SDBG would emerge. Although the present findings do not provide evidence that daily SDBG is associated with daily stress in this population, it is important to continue studying glycemic variability in order to gain a full picture of diabetes control and risks in patient populations.

Anxiety was not found to play a significant role in the relationship between daily stress severity and glycemic control. At the correlational level, RCMAS-2 total scores were related only to average DSS severity. There are several potential explanations for this. First, it is possible that different subtypes of anxiety would play a more meaningful role in these relationships. For example, relationships between fear of hypoglycemia (FOH) and glycemic control are mixed, but FOH is related to poorer quality of life in both children and their parents (Driscoll et al., 2016). FOH may therefore impact adolescents' approach to dealing with daily stressors and subsequent daily BG levels. Second, it is important to highlight the distinction between trait and state anxiety. Trait anxiety refers to an individual's general level of anxiety (which was measured in this

study), while state anxiety refers to in-the-moment anxiety levels. Specifically, the RCMAS-2 asks respondents to report on whether items are "true of you," as opposed to asking about their current state or their feelings in a given situation (Reynolds & Richmond, 2008). Previous studies examining anxiety in adolescents with T1D have found that while trait anxiety is related to BGM frequency, state anxiety is related to both BGM frequency and glycemic control (i.e., HbA1c; Herzer & Hood, 2010). Hilliard and colleagues (2011) also found that state anxiety levels were significantly related to HbA_{1C}; trait anxiety levels were not measured in this study. Thus, it is possible that trait anxiety affects daily adherence tasks but is not significantly related to objective outcomes such as BG levels or HbA_{1C}. In a recent review of anxiety in youth with T1D, Rechenberg and colleagues (2017) proposed that trait anxiety is related to FOH and hypervigilance of physiological symptoms, while state anxiety is more closely related to outcomes including HbA_{1C} and BGM frequency. Future research incorporating state anxiety into daily diary surveys, instead of assessing trait anxiety at baseline, may illuminate this relationship further.

It is also important to consider ways in which the timing of measure administration may have impacted participants' scores. Although RCMAS-2 scores should yield generic levels of trait anxiety, it is possible that anxiety symptoms were underreported given that participants were in a relatively low-stress camp environment when they completed the measure. As noted above, RCMAS-2 instructions do not indicate a specific reporting period, but instead the instructions ask participants whether or not each item is true of them. Adolescents have particular difficulty accurately reporting symptoms when compared to adults, especially when they are asked to estimate

their experiences over an extended or unspecified period (Kamphaus & Frick, 2005). Participants may have had difficulty estimating their anxiety symptoms while in a pleasant and stress-free environment, making them more likely to rely on cognitive heuristics to respond to items (Margetts et al., 2003). RCMAS-2 total T-scores in the present study were broadly unremarkable or subclinical in nature. Data on rates of clinical anxiety in this population are mixed; it is widely accepted that youth with T1D demonstrate higher rates of anxiety symptoms than their health peers, but regarding "clinically significant" scores, threshold cutoffs are inconsistent across studies (Buchberger et al., 2016). Thus, it is difficult to say how this sample compares to others regarding anxiety symptoms endorsed, but it is feasible that completing the measure while at camp depressed scores somewhat.

Lastly, it is worth noting that moderation analyses involving anxiety scores were likely underpowered to detect significance, given that *a priori* power analyses were conducted for the analyses proposed in Hypothesis 1. Therefore, it may be the case that a larger sample size would yield significant relationships between anxiety and other key study variables.

Taken together, the present findings indicate that while fluctuations in daily DSS severity account for some variability in daily MBG levels, there is more to the equation than was accounted for in this study. An important factor to consider, and one that was not measured here, is the role of individual coping styles in response to stressors. Existing research on coping styles in adolescents with T1D has revealed differences in diabetes outcomes based on individual coping styles. Broadly, avoidant (or emotion-focused) coping are related to poorer glycemic control as compared to approach (or problem-

focused) coping (Delamater et al., 1987; Graue et al., 2004). Jaser and White (2011) described three distinct coping strategies: primary control engagement (including problem-solving and emotional expression), secondary control engagement (including acceptance or cognitive restructuring), and disengagement (including withdrawal or denial). Primary control coping strategies were associated with the highest quality of life and best glycemic control. Importantly, secondary control coping was also associated with better glycemic control (as compared to disengagement), suggesting that secondary control may still be helpful for adolescents given that there are some aspects of diabetes that cannot be handled with problem-solving. In these cases, acceptance or cognitive restructuring appears to be adaptive. Disengagement was consistently associated with poor glycemic control.

Coping styles may thus be an important intermediate factor in the relationship between diabetes-specific stress and glycemic control and may explain why in our study, stress severity alone did not account for variations in daily BG levels. One study found that adolescents who perceive more diabetes-related distress also utilize avoidant coping styles, which results in poorer self-management and subsequently poorer HbA_{1C} (Iturralde et al., 2017). Maladaptive coping strategies, and particularly passive coping, have also been linked to low levels of resilience in this population (Yi-Frazier et al., 2015). This suggests that proactive problem-solving is the optimal approach when individuals encounter diabetes-related stressors. Additionally, low-income and minority racial/ethnic status have been linked to avoidant coping strategies in this population, suggesting that chronic stress experienced by these individuals may interfere with their ability to take a problem-focused approach to diabetes management (Jaser et al., 2012).

Thus, the relationship between diabetes-specific stress, coping strategies, and glycemic control of adolescents with T1D is an important area for future study.

Notably, age at diagnosis was a significant predictor of BG levels (both MBG and SDBG) in all the models reported in this paper. Younger age at diagnosis was consistently associated with higher MBG and SDBG (i.e., poorer glycemic control). This finding comports with existing research demonstrating poorer diabetes management and self-care behaviors in adolescents with longer T1D diagnosis duration as compared to adolescents diagnosed more recently (Austin et al., 2011; Chao et al., 2014). The present results underscore the importance of considering duration of diagnosis when estimating trajectories of glycemic control across adolescence.

The present findings must be interpreted in the context of the study's limitations. First, we did not obtain HbA_{1C} values for participants, given that we will not have access to their medical records. Research with individuals with T1D often includes HbA_{1C} values as measures of long-term glycemic control. We are therefore unable to draw conclusions about how these daily psychosocial processes and BG measures relate to glycemic control over a longer period of time. In future studies, it would be valuable to measure both daily BG levels using CGMs or glucometers and HbA_{1C} levels corresponding to the measurement period. This would allow researchers to explore how these daily processes contribute to long-term glycemic control in this population.

Additionally, as mentioned previously, the size of the present sample was likely not large enough to detect meaningful relationships in our moderation analyses. In order to be confident about the findings of these analyses, a larger sample size is warranted. It is also possible that significant relationships in this study would be furthered strengthened

by an increase in number of participants. Relatedly, a larger sample size may yield a more diverse participant population, which could shed light on the differential experiences of distinct racial or ethnic groups. Existing research has shown that not all youth with T1D experience stress in the same way. For example, Hispanic/Latinx emerging adults show a stronger association between DSS and poor glycemic control than do their non-Hispanic white counterparts, and Hispanic/Latinx individuals show greater impact of general stress on glycemic control (Butler et al., 2017). A sample with more racial/ethnic diversity, or one targeting minority populations, would illuminate potential disparities in daily disease processes between groups. That said, the racial/ethnic breakdown of the current sample is largely reflective of the demographic characteristics of youth with T1D in the U.S. (Miller et al., 2015).

Relatedly, it is important to consider the characteristics of the camp-attending population from which we recruited our sample. As discussed previously, this sample reported high rates of technology usage (e.g., 93% of participants reported using CGMs). Given the known diabetes-related benefits of CGM use for those with T1D (i.e., improved glycemic control; DeSalvo et al., 2018), it is likely that the present sample had lower MBG and SDBG than the average adolescent with T1D. There is also evidence that adolescents who attend diabetes camps are more involved in their diabetes care, and have more involved families, than the average adolescent with T1D (Chae et al., 2014). This may have impacted analyses by limiting the variability of BG outcome variables, and also limits the generalizability of the present results. Thus, it would be valuable to replicate the present study with a sample that is more representative of the general population of adolescents with T1D or a higher risk sample (e.g., adolescents with chronically high

Hb_{A1C} levels or those with low rates of technology use) to determine whether similar or different associations between diabetes-specific stress and glycemic control are present.

Finally, as with many studies using data of this nature, we are unable to draw conclusions of causality between daily diabetes-specific stress and glycemic control. This is due both to the fact that this study was not experimental in nature and to the fact that we could not establish temporal precedence of stress versus BG values. It is possible that on a given day, higher BG levels triggered diabetes-specific stress in participants; equally plausible, however, is the possibility that diabetes-specific stressors impacted participants' management of their BG and resulted in higher MBG values. Future research on daily disease management processes might include multiple daily measurement points, which could yield data that exhibit the unfolding of a temporal process. The constant and intensive nature of diabetes management calls for a close examination of causal processes between psychosocial and disease processes.

Implications

Despite its limitations, the present study offers a meaningful contribution to the literature on daily processes of adolescents' management of T1D. The association between fluctuations in daily diabetes-specific stress and same-day glycemic control highlights the need for clinicians to focus on bolstering adolescents' adaptive responses to daily disease-related stressors. Healthcare providers may incorporate interventions targeting coping and stress management that are feasible for adolescents to use daily. There have been some explorations of interventions to target DSS in individuals with T1D. DSS levels improved following multisystemic therapy (MST) with adolescents with chronically poorly controlled T1D (Ellis et al., 2005), although it is important to note that

MST is a relatively intensive and costly intervention and therefore not feasible for many T1D patients to engage in. Ellis and colleagues (2018) have recently conducted an initial exploration of mindfulness-based stress reduction aimed at improving DSS in emerging adults, although results were preliminary, and additional research is warranted.

Researchers in this area have suggested lower cost strategies to help adolescents manage DSS, including resilience-building interventions, given that resilience is associated with lower levels of diabetes distress and improved quality of life in adolescents with T1D (Yi-Frazier et al., 2015). Maladaptive coping styles are likely a meaningful point of clinical intervention, given existing research demonstrating links between stress, coping, and glycemic control in adolescents with T1D (Iturralde et al., 2017; Jaser & White, 2011). Adolescents who use approach coping skills are more likely to continue to engage in diabetes management behaviors in the face of stressors. Teaching adolescents to use proactive problem-solving approaches when they encounter diabetes-specific stressors may bolster their ability to handle such stressors and improve their ability to maintain good glycemic control despite stressors. Brief stress management interventions (e.g., diaphragmatic breathing, mindfulness, and relaxation) may be especially relevant to these adolescents, as these are strategies that can easily be incorporated into their daily lives. Additionally, it is important to consider adolescents' life experiences when targeting optimal diabetes management. Low-income and minority youth may require additional support with managing diabetes stress, especially depending on how they cope with poverty and discrimination (Jaser et al., 2012). Culturally relevant interventions are also warranted to bolster coping in an effective manner that

encompasses holistic considerations of the individual and their environment (Yang et al., 2019).

Relatedly, findings of the current study highlight the importance of distinguishing between perceived GS versus DSS when planning interventions for individual adolescents. High levels of GS may call for generic stress management skills for school- and peer-related stress while promoting good diabetes management in a busy schedule. Adolescents with higher levels of DSS may benefit instead from interventions targeting thoughts and behaviors regarding diabetes management tasks. For example, it may be valuable to discuss strategies for checking BG levels and dosing appropriately for food in social situations where youth may feel embarrassed.

Lastly, the use of EMA methodology in this study to collect intensive longitudinal data provides further support that such methods are feasible for use with adolescents and can provide meaningful results. Compared to our pilot testing, approximately the same percentage of participants agreed to complete daily diaries following camp, and a much larger percentage of those participants completed BG uploads to Tidepool®. This increase may have been due to the introduction of incentives, and it is possible that additional incentives would boost participant engagement even further. Researchers should continue to develop and utilize EMA designs to further advance the literature on psychosocial correlates of disease outcomes in youth with chronic illnesses.

Conclusions

The present study utilized innovative methods to collect intensive longitudinal data, which allowed for the examination of both between- and within-subjects variance in daily stressors. Notably, results revealed distinctions in the predictive roles of average

DSS severity versus daily fluctuations in DSS severity. These findings highlight the importance of examining both between- and within-person psychosocial processes in individuals with T1D in order to fully understand the mechanisms underlying disease management. These data allow us to clarify which daily dynamics and which trait-level differences play meaningful roles in daily health behaviors and outcomes. The current findings provide further evidence, in accordance with prior studies (e.g., Berg et al., 2017; Lansing et al., 2016), that intra- and interindividual processes are often distinct and differentially associated with medical outcomes for youth with T1D. Additionally, objective BG data were collected to quantify glycemic control, while other studies of this nature have relied on self-report data. Our results demonstrating the link between fluctuations in daily DSS severity with concurrent MBG levels provide additional support for the need to identify adolescents' diabetes-related stressors and implement interventions aimed at daily stress management. By focusing on both intra- and interindividual processes in this population, the present study enhances our understanding of adolescents' daily psychosocial functioning and how it relates to a consequential diabetes outcome, daily blood glucose levels. Continued development and improvement of brief, feasible interventions to help adolescents maintain optimal glycemic control despite inevitable stressors will enable individuals with T1D to thrive.

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Table 1

EMA Studies of Adolescents with Type 1 Diabetes

Authors	Theoretical Constructs	EMA Collection Method	EMA Frequency & Duration	Age Range	Reminders	Incentives	Mean Response Rate
Baucom et al. (2015)	Depressive symptoms, stress severity, adherence behaviors	Online survey	Once daily, 14 days	17 to 18 years	Nightly reminders via text message or phone call	No information provided	81.4%
Berg et al. (2013)	Parental persuasive strategies, daily diabetes problems	Online survey	Once daily, 14 days	10 to 14 years	Nightly reminders via phone call	$50 for initial session, $4 per completed diary	91.5%
Berg et al. (2014)	Adherence behaviors, self-regulation	Online survey	Once daily, 14 days	17 to 18 years	Nightly reminders via text message or phone call	$50 for initial session, $5 per completed diary	79.1%
Berg et al. (2017)	Family context, adherence behaviors, adolescent disclosure, self-regulation	Online survey	Once daily, 14 days	17 to 18 years	Nightly reminders via text message or phone call	$50 for initial session, $5 per completed diary	80.1%
Borus et al. (2013)	Adherence behaviors, social context	Handheld computer	Four times daily, 14 days	14 to 18 years	N/A	$100 for completing >70% of diaries	63% (median)

Authors	Theoretical Constructs	EMA Collection Method	EMA Frequency & Duration	Age Range	Reminders	Incentives	Mean Response Rate
Fortenberry et al. (2009)	Diabetes task competence/self-efficacy, daily affect	Paper/pencil	Once daily, 14 days	11 to 16 years	Phone call reminders every other day	$10 for initial packet, $3 per completed diary	85.7%
Fortenberry et al. (2012)	Negative affect, diabetes problems, perceptions of control, adherence behaviors	Online survey	Once daily, 14 days	10 to 15 years	As-needed reminder phone calls	$4 per completed diary	91.4%
Hema et al. (2009)	Daily stressors and coping strategies	Paper/pencil	Once daily, up to 21 days	8 to 18 years	No information provided	No information provided	14.15 entries
Lansing et al. (2016)	Self-control, diabetes negative affect, daily diabetes problems	Online survey	Once daily, 14 days	10 to 14 years	Nightly reminders via phone call	$50 for initial session, $4 per completed diary	91.5%
Mulvaney et al. (2012)	Self-care/adherence behaviors	Phone calls	Twice daily, 10 days	12 to 17 years	N/A	No information provided	60.2%
Wiebe et al. (2018)	Executive function, diabetes goal planning, adherence behaviors	Online survey	Once daily, 14 days	17 to 18 years	Nightly reminders via text message or phone call	$50 for initial session, $5 per completed diary	81.4%

Table 2

Demographic Characteristics

Variable	*M*	*SD*	Range	*n*	%
Gender					
Female				30	68.2
Male				14	31.8
Age at testing (years)	15.35	1.05	13.39 – 17.64		
Race (select all that apply)					
American Indian/Alaska Native				0	0
Asian				5	9.8
Black/African American				2	3.9
Hispanic or Latina/o				7	13.7
Middle Eastern				1	2.0
Native Hawaiian or Other Pacific Islander				1	2.0
White or European American				35	68.6
Other				4	7.8
Age at diagnosis (years)	7.69	3.36	1.50 – 13.50		
Uses a pump				41	93.2
Uses a CGM/sensor				42	82.4

Table 3

Descriptive Statistics of Key Study Variables

Variable	*M*	*SD*	Range
Mean blood glucose	179.63	51.08	74.67 – 364.83
Standard deviation of blood glucose	62.20	26.51	16.40 – 189.13
General stress severity	0.54	0.69	0.0 – 3.6
Diabetes-specific stress severity	0.86	1.17	0.0 – 4.6
Revised Childhood Manifest Anxiety Scale Total T-score	55.27	8.00	33 - 71

Table 4

Bivariate Correlations Between Aggregated Key Study Variables

Variable	1	2	3	4
1. General stress severity	--			
2. Diabetes-specific stress severity	.68*	--		
3. Mean daily BG (MBG)	.24	.25	--	
4. Standard deviation of daily BG (SDBG)	.19	.29	.73*	--
5. Revised Childhood Manifest Anxiety Scale, Total T-scores	.23	.44*	.13	.14

*$p < .01$

Table 5

Multilevel Models Predicting Mean Daily Blood Glucose Levels

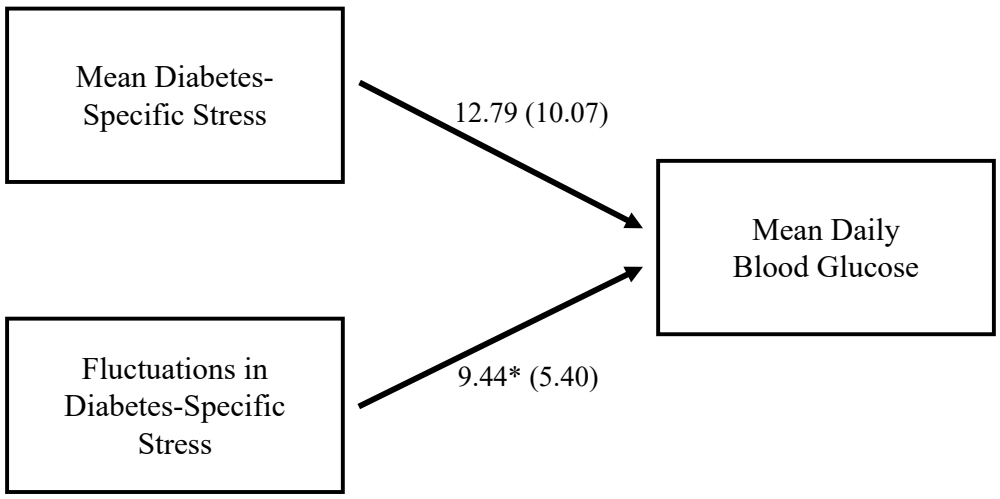
Variable	*B*	*SE*	*t*	95% CI
Daily Diabetes-Specific Stress (DSS) Predicting MBG				
Intercept	243.12	16.92	14.37***	206.58 – 279.66
Intraindividual (Level 1)				
Day	0.68	1.44	0.47	-2.18 – 3.53
Fluctuations in Daily DSS	9.44	4.50	2.10*	0.0 – 18.89
Interindividual (Level 2)				
Gender	-20.32	13.52	-1.50	-50.35 – 9.71
Age at diagnosis	-6.40	1.78	-3.59**	-10.40 – -2.40
Mean DSS	12.79	10.07	1.27	-8.85 – 34.43
Daily General Stress (GS) Predicting MBG				
Intercept	234.86	15.70	14.96***	203.10 – 266.63
Intraindividual (Level 1)				
Day	0.52	1.30	0.40	-2.15 – 3.20
Fluctuations in Daily GS	5.54	5.86	0.95	-7.26 – 18.35
Interindividual (Level 2)				
Gender	-14.34	12.07	-1.24	-39.34 – 9.46
Age at diagnosis	-5.78	1.59	-3.64**	-9.01 – -2.55
Mean GS	18.76	11.06	1.70	-3.56 – 41.07
Daily DSS and Anxiety Predicting MBG				
Intercept	207.51	54.89	3.78**	95.89 – 319.14
Intraindividual (Level 1)				
Day	0.98	1.89	0.52	-2.72 – 4.68
Fluctuations in Daily DSS	70.87	34.16	2.08	-4.88 – 146.62
Fluctuations in Daily DSS*Anxiety	-1.08	0.60	-1.79	-2.43 – 0.27

	Interindividual (Level 2)			
Gender	-18.97	15.21	-1.25	-50.05 – 12.11
Age at diagnosis	-6.93	1.91	-3.63**	-10.85 – -3.01
Mean DSS	9.09	11.15	0.82	-13.60 – 31.77
Anxiety	0.69	0.98	0.71	-1.30 – 2.69
	Daily GS and Anxiety Predicting MBG			
Intercept	207.39	43.20	4.80***	120.11 – 294.68
	Intraindividual (Level 1)			
Day	0.47	1.27	0.37	-2.16 – 3.09
Fluctuations in Daily GS	-49.43	37.42	-1.32	-130.54 – 31.68
Fluctuations in Daily GS*Anxiety	0.97	0.65	1.49	-0.47 – 2.41
	Interindividual (Level 2)			
Gender	-18.12	12.73	-1.42	-43.78 – 7.54
Age at diagnosis	-5.33	1.54	-3.45**	-8.45 – -2.21
Mean GS	19.72	10.69	1.84	-1.80 – 41.24
Anxiety	0.48	0.77	0.63	-1.07 – 2.04

*$p < .05$, **$p < .01$, ***$p < .001$

Figure 1

Fluctuations in Diabetes-Specific Stress Predict Daily MBG, While Mean Diabetes-Specific Stress Does Not



Note. Covariates included in these models are discussed in the text and presented in Table 5; they are not included here to reduce complexity in the figures.

*$p < .05$.

Appendix A

Revised Children's Manifest Anxiety Scale – Second Edition

Directions: The sentences on the page tell how some people think and feel about themselves. Read each sentence carefully, and then circle the Letter that shows your answer. Select Yes if you think the sentence is true about you. Select No if you think it is not true about you. Give an answer for every sentence, even if it is hard to choose one that fits you. There are no right or wrong answers. Only you can tell us how you think and feel about yourself. Remember, after you read each sentence; ask yourself "Is this true about me?" If it is, select Yes. If it is not, select No.

1. I have trouble making up my mind.	YES	NO
2. I get nervous when things do not go the right way for me.	YES	NO
3. Others seem to do things easier than I can.	YES	NO
4. I like everyone I know.	YES	NO
5. Often I have trouble getting my breath.	YES	NO
6. I worry a lot of the time.	YES	NO
7. I feel bad if people laugh at me.	YES	NO
8. I am afraid of a lot of things.	YES	NO
9. I am always kind.	YES	NO
10. I get mad easily.	YES	NO
11. I worry what my parents will say to me.	YES	NO
12. I feel that others do not like the way I do things.	YES	NO
13. I am afraid to give a talk to my class.	YES	NO
14. I always have good manners.	YES	NO
15. It is hard for me to get to sleep at night.	YES	NO
16. I worry about what other people think of me.	YES	NO
17. I feel alone even when there are people with me.	YES	NO
18. I get teased at school.	YES	NO
19. I am always good.	YES	NO
20. Often I feel sick in my stomach.	YES	NO
21. My feelings get hurt easily.	YES	NO
22. My hands feel sweaty.	YES	NO
23. I worry about making mistakes in front of people.	YES	NO
24. I am always nice to everyone.	YES	NO
25. I am tired a lot.	YES	NO
26. I worry about what is going to happen.	YES	NO
27. Other people are happier than I am.	YES	NO
28. I am afraid to speak up in a group.	YES	NO
29. I tell the truth every single time.	YES	NO
30. I have bad dreams.	YES	NO
31. I feel someone will tell me I do things the wrong way.	YES	NO
32. I get angry sometimes.	YES	NO
33. I worried about being called on in class.	YES	NO

34. I wake up scared sometimes.	YES	NO
35. I worry when I go to bed at night.	YES	NO
36. It is hard for me to keep my mind on my schoolwork.	YES	NO
37. I sometimes say things I should not say.	YES	NO
38. I fear other kids will laugh at me in class.	YES	NO
39. I worry about someone beating me up.	YES	NO
40. I wiggle in my seat a lot.	YES	NO
41. I am nervous.	YES	NO
42. A lot of people are against me.	YES	NO
43. I have told a lie.	YES	NO
44. I often worry about something bad happening to me.	YES	NO
45. I fear other people will laugh at me.	YES	NO
46. I have too many headaches.	YES	NO
47. I worry that others do not like me.	YES	NO
48. I get nervous around people.	YES	NO
49. I worry about saying something dumb.	YES	NO

Appendix B

Demographics Survey

1. What is your date of birth? _____
2. Do you have type 1 diabetes? Yes No
3. How old were you when you were diagnosed with type 1 diabetes? _____
    a. Do you know the date of your diagnosis?_____
4. What is your gender? _____
5. What grade will you be in this fall? _____
6. What is your race/ethnicity? (Select one or more responses)

    ☐ American Indian/Alaska Native

    ☐ Asian

    ☐ Black or African American

    ☐ Hispanic or Latina/o

    ☐ Middle Eastern

    ☐ Native Hawaiian or Other Pacific Islander

    ☐ White or European American

    ☐ Other

7. Do you use a pump?
    a. Yes – what brand? _____
    b. No
8. Do you use a CGM/sensor?
    a. Yes – what brand? _____
    b. No

Appendix C

Daily Stress Survey

Think about if each of these things has happened to you today. Select YES or NO for each item. For each item you say YES to, select how stressful it was for you today. For the first five items, if you say YES, select how much this event was related to your diabetes.

Argument or disagreement with someone	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES					
	If you said YES: How much was this event related to your diabetes?				
NO	1 Not at all	2 A little	3 Somewhat	4 Very much	5 Completely
Problem with school or schoolwork	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES					
	If you said YES: How much was this event related to your diabetes?				
NO	1 Not at all	2 A little	3 Somewhat	4 Very much	5 Completely
Problem with work or chores	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES					
	If you said YES: How much was this event related to your diabetes?				
NO	1 Not at all	2 A little	3 Somewhat	4 Very much	5 Completely

Having to deal with other people's problems YES NO	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
	If you said YES: How much was this event related to your diabetes?				
	1 Not at all	2 A little	3 Somewhat	4 Very much	5 Completely
Problem related to where you live or things you own YES NO	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
	If you said YES: How much was this event related to your diabetes?				
	1 Not at all	2 A little	3 Somewhat	4 Very much	5 Completely

Problem with high or low blood sugar YES NO	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
Forgetting or skipping a blood glucose test YES	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get

NO					
Taking the wrong amount of insulin	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES NO					
Feeling bad because of your diabetes	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES NO					
Problem with pump or continuous glucose monitor	If you said YES: How stressful was this today?				
	1 Not at all stressful	2 A little stressful	3 Somewhat stressful	4 Very stressful	5 As stressful as it can get
YES NO					