An Examination Of The Role Of Neurocognitive Functioning In Illness Management Among Adolescents With Type 1 Diabetes

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AN EXAMINATION OF THE ROLE OF NEUROCOGNITIVE FUNCTIONING IN ILLNESS MANAGEMENT AMONG ADOLESCENTS WITH TYPE 1 DIABETES

by

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ABSTRACT

AN EXAMINATION OF THE ROLE OF NEUROCOGNITIVE FUNCTIONING IN ILLNESS MANAGEMENT AMONG ADOLESCENTS WITH TYPE 1 DIABETES

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Children and adolescents living with Type 1 Diabetes Mellitus (T1DM) face many challenges in their daily lives due to the extensive care tasks that the illness requires. Adolescence is a period of development in which treatment adherence and metabolic control has been found to greatly decline. Research examining correlates of this decline in self-management has tended to focus on familial and psychosocial variables such as parental involvement and T1DM-related conflict. The period of adolescence is also marked by several changes in the development of the frontal lobes and prefrontal cortex, which are areas of the brain that are central to executive functioning abilities. The present study will examine executive functioning among adolescents with T1DM to explore its relationship with treatment adherence, metabolic control, and with measures of family involvement in the management of T1DM.

Eighty four adolescents diagnosed with T1DM (ages 12-18) and their parents completed the study. Parents and adolescents completed questionnaires assessing adolescents' executive functioning, parental involvement, monitoring, and conflict. Adolescents completed neuropsychological measures assessing several aspects of their neuropsychological functioning including their executive functioning, intelligence, and memory. In addition to this, adolescents' medical records were reviewed to collect hemoglobin A1c (HbA_{1c}) values, which represent levels of metabolic control.

In general, results supported our hypotheses, in that adolescents with better developed parent and self-reported executive functions tended to display better adherence to their T1DM treatment regimen. Additionally, parent and self-reports of adolescent executive functioning were shown to be significant predictors of adherence beyond the contributions of several demographic and family functioning variables. Examination of parents' contributions to adolescents' T1DM management revealed that parental involvement was a significant moderator of the relationship between adolescents' executive functioning and treatment adherence, such that parental involvement had a larger impact for adolescents who demonstrated poorer executive functions.

Overall, the study finds support for measuring executive functioning abilities in adolescents with T1DM as a potentially important contributing factor in aiding adolescents with the complex management of this illness.

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Children and adolescents living with type 1 diabetes mellitus (T1DM) face many challenges in their daily lives due to the extensive care tasks that their illness often requires. During the adolescent years, youth are particularly at risk for many of the complications that accompany poor treatment adherence (Anderson, Auslander, Jung, Miller, & Santiago, 1990). Many of the difficulties that adolescents encounter with treatment adherence appear to be correlated with specific challenges experienced in relation to several cognitive, psychological, and social changes that occur throughout adolescence. There are several salient factors that have been demonstrated to be significant predictors of treatment adherence and metabolic control. Specifically, some of the social and psychological factors include the amount of parental involvement in T1DM management, parental monitoring of adherence behaviors, and T1DM- related conflict that is present within the family (Ellis, Podolski, Frey, Naar-King, Wang, & Moltz, 2007; Miller-Johnson et al., 1994; Palmer, Berg, Wiebe, Beveridge, & Korbel, 2004).

Adolescence is also a period in which certain areas of the brain show significant changes and development. Specifically, the most dramatic changes have been found to occur within the frontal lobes and prefrontal cortex, which are areas of that brain that are responsible for executive functioning abilities (Blakemore & Choudhury, 2006). Executive functioning, which involves an individual's ability to plan, self-monitor, and use working memory, has been studied extensively along with other related cognitive abilities in children with T1DM. Although research has demonstrated that children and adolescents with T1DM display moderately worse executive functioning abilities when compared to healthy controls, there has been little research examining the functional outcomes associated with these deficits (Gaudieri, Greer, Chen, & Holmes, 2008). Given the complexity of the diabetes treatment regimen, executive functions likely encompass many of the skills that are needed in order for individuals to successfully manage all of the self-care tasks that they are supposed to maintain.

Overall, there appears to be an established body of literature examining the psychological and social factors that account for poor treatment adherence during adolescence; however, there has been little research examining how cognitive functioning may impact treatment adherence and metabolic control. The current study will also further explore the multifaceted ways in which the family contributes to T1DM management among adolescents while taking into account adolescents' incomplete cortical development and evolving cognitive capacity.

Type 1 Diabetes Mellitus

T1DM is the second most prevalent chronic illness among children and adolescents in the United States, and it affects one in 500-600 children (Wysocki, Greco, & Buckloh, 2003). T1DM is characterized by the autoimmune destruction of pancreatic beta cells that results in an inability of the body to produce insulin, which is a hormone that facilitates the metabolic breakdown of glucose in the blood. Glucose is a primary source of our body's energy, comes from the food we consume, and can include complex carbohydrates or starches and fast-acting, simple sugars. When carbohydrates are consumed, they are absorbed by the gastrointestinal tract and carried throughout the bloodstream to provide the body's cells with the energy they need to function. However, in order for glucose to permeate the cell membrane, the hormone insulin must be present to facilitate this process (Beaser, 2007). Insulin is manufactured in the pancreas, which is an organ that serves as part of the small intestines and lies below the stomach. Within the pancreas, insulin is produced in the islets of Langerhans, which contain pancreatic beta cells. These cells serve a regulatory function by secreting the appropriate amount of insulin in response to the concentration of glucose detected in the blood. This autonomic response typically occurs in healthy individuals within 15 minutes after food consumption and is accurate within 2 mg/dl of the precise amount of insulin that is required (Watkins, Drury, & Howell, 1996). In individuals with T1DM, the body's autoimmune defenses, which usually target foreign substances such as viruses, attack the pancreatic beta cells and prevent the body from producing insulin. The body begins to essentially starve itself because the cells are not able to metabolize the sugars for energy. This results in severely high levels of glucose in the blood, which is a condition known as hyperglycemia (Beaser, 2007).

T1DM, which previously was called juvenile onset diabetes, typically is diagnosed in childhood and has a mean age of onset between 9 and 15 years of age (Watkins et al., 1996). The disease is typically diagnosed following symptoms of polyurea, polydipsea, and polyphagia as well as weight loss and fatigue. Many families do not seek immediate treatment for these symptoms due to their resemblance to the common flu. Hyperglycemia (>126 mg/dl on repeated measures over time) must be established in order to make a diagnosis (American Diabetes Association, 2008). If insulin is not administered to these patients, they will experience diabetic ketoacidosis (DKA), which is a condition in which the body begins to break down fatty acids in the liver. This process results in the secretion of ketones into the bloodstream, which provides energy for the brain but lowers the pH of the blood to acidic levels. Patients in DKA experience nausea and vomiting, and if they are not treated for an extended period of time, the symptoms can eventuate to a state of coma or death (Beaser, 2007).

Following diagnosis of T1DM, there is an intensive level of daily care tasks that must be completed, which include blood glucose monitoring several times per day, administering insulin injections with respect to the type and amount of food eaten, as well as maintaining a strict diet and engaging in regular exercise (Greening, Stoppelbein, & Reeves, 2006). Because of the variable nature of the illness and frequently changing insulin requirements, children and adolescents with T1DM often experience modifications in their treatment regimen several times per year. To assess the level of metabolic control patients maintain, physicians obtain a measurement of the amount of glycosylated hemoglobin (HbA_{1c}) that is present in the blood. HbA_{1c} reflects the average level of blood glucose control the individual has maintained over the previous 6-8 weeks. Higher numbers reflect poorer control. The average healthy individual has an HbA_{1c} value of less than 6.5%, but this is usually higher in individuals with diabetes, who aim to maintain a value less than or equal to 7.4% (American Diabetes Association, 2008). If proper care is not maintained, there are several short-term consequences that include ketoacidosis as well as hyper- and hypoglycemic (state of severely low, < 50mg/dl, blood glucose levels) episodes. There can be severe consequences to ill-maintained T1DM. Long-term effects include, but are not limited to, restricted joint mobility, heart disease, blindness, and early death (Beaser, 2007).

Treatment Adherence

Patient adherence to medical treatment regimen is an area of study that has gained increasing interest over the past few decades. There are many definitions of what constitutes treatment adherence, but one of the most widely accepted definitions was provided by Haynes (1979) who described treatment adherence as "the extent to which a person's behavior (in terms of taking medications, following diets, or executing lifestyle changes) coincides with medical or health advice" (p. 2). Over the years, the terms used to describe this construct have changed to reflect a more active role on the part of the patient. Early adherence research used the term "treatment compliance," which connotes a sense of blind obedience to the recommendations of the provider. The term "adherence" is now used to describe this construct and implies a more collaborative relationship among the patient and physician in which each party plays an active role in planning and implementing a treatment regimen that will work best for the individual's needs (Myers & Midence, 1998). Although physicians serve as the experts who impart recommendations to patients regarding the best course of treatment, the decision to adhere is ultimately up to the patient to decide whether or not he/she will implement the recommendations. For children and adolescents with chronic illnesses, this responsibility falls not only on the child but also on the parents to manage within a family context (Anderson et al., 1990; Rapoff, 2010).

Adherence can be viewed as a categorical or a dimensional construct. Although much of the research has examined it categorically, meaning that individuals are judged to be either adherent or nonadherent, this approach is limiting because of the subjectivity inherent to labeling self-care behaviors. There is no single definition for determining what constitutes adequate adherence, and thus it is best understood as a dimensional construct in which individuals may be fully or partially adherent to various aspects of the treatment regimen (LaGreca & Bearman, 2003). Due to the inexact medical science that is involved in chronic illness management, adherence behaviors are never perfectly correlated with symptom relief or maintaining illness control. Research has widely demonstrated that there is a moderate relationship between treatment adherence and illness control for the management of most chronic illnesses (e.g. DiMatteo, Giordani, Lepper, & Croghan, 2002; Johnson, 1994). Consequently, nonadherence has proven to be a major health concern in the United States both in minor as well as major health conditions. Overall rates of adherence across all medical conditions are believed to be less than 50% and represent a major public health issue in America. Nonadherence to medical regimen is estimated to cost about 100 billion dollars every year due to unnecessary hospitalizations and additional diagnostic tests and medication (DiMatteo, 2004; Rapoff, 2010).

Although the principles of adherence are similar across illness conditions, there is significant variability across illness groups in terms of the treatment regimen requirements. For patients with chronic health conditions such as T1DM, adherence is even lower than it is for less pervasive, acute health conditions, despite the consequences of nonadherence usually being much more severe (Christensen, 2004). Among chronic health conditions there are differences in treatment adherence as well, with disease chronicity serving as a significant correlate of treatment adherence (Rapoff, 2010). About 50% of children with asthma improve their illness status as a direct effect of their treatment compliance and are asymptomatic as adolescents (Lemanek, 1990). This is in sharp contrast to children and adolescents who are diagnosed with T1DM, whose treatment compliance is aimed at managing the symptoms of a lifelong illness, and consequently they tend to display poorer treatment adherence (LaGreca & Bearman, 2003).

T1DM is one of the most psychologically and physically demanding chronic illnesses to care for due to the multitude of interdependent tasks that are required (Cox & Gonder-Frederick, 1992). For individuals to maintain adequate control of their T1DM, they are typically instructed to check their blood glucose (BG) values 4-6 times per day (American Diabetes Association, 2008). From the value that these BG checks yield, individuals are expected to make adjustments, either by dosing the proper amount of insulin to bring their BG value down or by consuming a fast-acting sugar to bring their BG up into the desired range. Other requirements of the T1DM treatment regimen include following dietary restrictions while making sure to measure the grams of carbohydrates consumed in every serving to ensure the proper dose of insulin that must be administered. It is also important to engage in daily exercise to help the body to regulate its BG levels (Johnson, 1993).

Research has provided support for the interrelatedness among some components of the treatment regimen. One study (Glasgow, McCaul, & Schafer, 1987) found that when individuals experienced difficulties following dietary recommendations, they also tended to be less adherent to their BG monitoring and insulin administration as well. These tasks are directly related to one another and involve a certain level of planning and coordination to complete. Interestingly, there was no relationship found among these aspects of the treatment regimen (i.e. patient adherence to diet, blood glucose monitoring, and insulin administration) and the amount of exercise in which the youth engaged in.

This finding suggests that some of the tasks may be more difficult to perform either due to their complexity and time requirements or because they are duties that parents have more responsibility for maintaining. Exercise is one aspect of the treatment regimen than does not require extensive planning. Findings such as this speak to the importance of studying the various aspects of the treatment regimen separately to determine which components of treatment are the most difficult to adhere to.

Given the subjective nature of treatment adherence, there have been several methods utilized to measure this nebulous construct. Some of these methods of assessing adherence include self-report questionnaires, structured interviews, diary methods, and electronic monitors. Although metabolic control, as measured by HbA_{1c} values, is sometimes used as a measures of adherence, it is actually a measure of outcome, rather than a measure of process (Kyngas, Kroll, & Duffy, 2000). There has been a significant amount of evidence demonstrating a strong correlation between adherence behaviors and HbA_{1c} values (Hood, Peterson, Rohan, & Drotar, 2010). Yet, this significant relationship is not always found due to many other biological and psychosocial factors that contribute to HbA_{1c} values. It is important for research studies to examine the quality of treatment adherence as well as levels of metabolic control to gain a comprehensive picture that includes both the process of self-care as well as the outcome of it.

Despite the variety of methods of measuring adherence and the multitude of research that has been conducted examining the efficacy of each, there still does not appear to be a "gold standard" approach to assessing adherence (Quittner, Espelage, Ievers-Landis, & Drotar, 2000). Quittner and colleagues (2008) have suggested that research assessing treatment adherence should use at least two different methods of assessment (i.e., self-report questionnaires, daily diaries, or physiological measures), yet much of the research in this area fails to include multiple measures, primarily due to the practical challenges inherent to additional measurement. A multi-assessment method corrects for some of the biases that are associated with the biological (i.e. hormonal influence), as well as self-reported (i.e., social desirability of responses) evaluations of adherence.

Treatment Adherence and Metabolic Control Among Adolescents With T1DM

Adolescence is a period of development that is generally associated with the lowest levels of treatment adherence and metabolic control across the lifespan (Anderson, et al., 1990; Miller-Johnson et al, 1994) with hospitalizations and episodes of ketoacidosis being most prevalent during middle adolescence (Glasgow et al., 1991). One study (Weissberg-Benchell et al., 1995) examining adolescents' adherence to a T1DM treatment regimen found that 29% of adolescents had missed blood glucose tests, 29% had falsified blood glucose test results, and 25% had skipped their insulin doses. Adolescents endorsed several reasons for this mismanagement, which included forgetting about their T1DM management tasks, not feeling that the care tasks were necessary or important, or acting oppositionally in response to the pressure they felt from physicians and family members to maintain good levels of control. What was even more concerning than the levels of mismanagement that adolescents displayed was the vast underreporting of mismanagement behaviors by their parents, which demonstrates a lack of parental involvement or monitoring. There has been a significant amount of research examining the salient family factors that are correlated with adolescent mismanagement. Specific factors that have been found to be related to poor treatment adherence during this developmental period include the amount of parental involvement and parental monitoring of adolescents' T1DM management and the amount of parent-adolescent conflict that is experienced in the home.

Parental involvement in adolescents' T1DM management.

The family plays an important role in helping adolescents successfully manage their T1DM. Due to the complexities of the treatment regimen, parents assume most of the responsibility for care tasks in early childhood because children and preadolescents do not possess the cognitive maturity it takes to plan for and organize a flexible diabetes regimen (Golden, 1999). However, during adolescence, a transition in care responsibility occurs in which parents begin to encourage adolescents to become more autonomous with their illness tasks (Weissberg-Benchell, Wolpert, & Anderson, 2007). During this transitional period, parents abdicate some of the responsibility for maintaining adolescents' T1DM tasks, and there is an expectation that youth will begin taking more responsibility accordingly. However, this process is not as synchronous as parents and providers often believe it will be. Although research has demonstrated the benefits of shared illness management throughout adolescence (Helgeson, Reynolds, Siminerio, Escobar, & Becker, 2008), in an environment with shared responsibilities, there may not always be clear expectations about who is responsible for which tasks (Dashiff, 2003).

The care transition among parents and adolescents is most often not a one-time event in which responsibilities are handed over from one individual to the other. Instead, the transition is a much more involved process in which parents and adolescents learn to negotiate the care regimen in concert with one another in a collaborative partnership. According to individuation theory, parents and their children have relationships that drastically change during the adolescent years (Youniss & Smollar, 1985). Adolescents learn to become autonomous through changes in the parent-child relationship which encourage their attempts towards the mastery of psychological, emotional, and behavioral tasks (Barber, 2002). When the child is young the relationship is unilateral in nature; however, as the child enters adolescence, it becomes more egalitarian. It is not an adolescent's separation from his/her parents that allows him/her to become autonomous, rather, autonomy development is rooted in a reciprocal relationship between the parent and adolescent, which fosters an environment of acceptance and individuation (Noack & Buhl, 2005). Individuation theory is directly applicable to the care of T1DM, which is most successfully managed within a family context. Research has widely demonstrated that maintaining parental involvement throughout adolescence is associated with a variety of positive outcomes related to T1DM management (e.g. Anderson et al., 1990; Anderson, Ho, Brackett, Finkelstein, & Laffel, 1997; Helgeson et al., 2008). Adolescents who are fully autonomous with their T1DM management are more likely to display poorer treatment adherence and poorer diabetes knowledge and have more T1DM-related complications and hospitalizations (Wysocki et al., 1996).

The majority of studies examining care transition and familial management during adolescence have been cross-sectional, which limits the conclusions that can be drawn in determining pathways of effect. Helgeson and colleagues (2008) conducted a two-year longitudinal study which provided evidence that sharing illness care responsibilities between parents and adolescents makes a significant impact on the psychological and physical health of adolescents with T1DM. A greater amount of adolescent-perceived parent-youth shared responsibility predicted less depression among adolescents, higher diabetes self-efficacy, and better levels of metabolic control. The positive effects of shared responsibility were consistent throughout the adolescent years but were especially prevalent during later adolescence. This provides strong evidence for the benefits of shared illness management among parents and adolescents not only early in the care transition process but also throughout adolescence.

Maintenance of T1DM care requires complex physical and mental processes which involve resourceful decision making and complex planning behaviors in order to maintain diabetes control (DCCT, 1994). Certain aspects of the T1DM regimen require more of this advanced cognitive ability. A study examining the development of the Diabetes-Specific Parental Support for Autonomy Scale demonstrated that the only parental support behavior related to adolescents' autonomy development was the sharing of insulin administration responsibilities, which is the task that represents the most complex skill (Hanna, DiMeglio, & Fortenbury, 2005). It is possible that adolescents become overwhelmed when they are burdened by the responsibilities associated with many T1DM care tasks in a manner that is unshared and unsupervised by parents, which may lead to negative psychosocial outcomes and inadequate treatment adherence.

Parental monitoring of adolescents' T1DM management.

Shared T1DM management among parents and adolescents can take many different forms. Parents can serve as models for adolescents in taking care of the majority of illness tasks, parents and adolescents can share the care tasks equally, or parents can be more removed and observe adolescents' self-care to ensure completion and accuracy. The latter approach refers to parental monitoring behavior, which is a construct of interest that has recently received more attention in the study of adolescent

T1DM management. Parental monitoring includes behaviors that range from obtaining information about a child's activities to direct oversight of those activities (Ellis, Templin, Naar-King, & Frey, 2008) and has been associated with positive academic outcomes (Rodgers & Rose, 2001) and reduced alcohol and drug abuse (Li, Stanton, & Feigelman, 2000). Monitoring is different from parental involvement, which has been frequently studied among adolescents with T1DM and typically involves measuring the amount of instrumental care the parent is providing to the child (Anderson et al., 1990; Wysocki & Gavin, 2006). When parents monitor self-care behaviors, it encourages adolescents to autonomously manage their T1DM care tasks while parents provide a phased and supported transition of care (Ellis et al., 2007).

Research examining the role of parental monitoring of T1DM care tasks during adolescence has demonstrated that mothers' and fathers' reports of T1DM monitoring behaviors are positively associated with adolescent treatment adherence and indirectly related to metabolic control. These associations were not found for general parental monitoring behaviors. Additionally, parental monitoring accounted for a significant amount of variance in predicting adolescents' treatment adherence beyond the contribution of parental support for T1DM care (Ellis et al., 2007).

Parental involvement and monitoring of diabetes care are constructs that have demonstrated efficacy as predictors of adolescent treatment adherence. There does not appear to be any research examining the role of parental involvement or monitoring of T1DM care tasks with regard to adolescents' cognitive maturity. Given the advanced cognitive skills necessary to maintain a flexible T1DM regimen, some adolescents who are more cognitively developed may have a distinct developmental advantage in planning and coordinating their self-care. Conversely, adolescents who have poorer cognitive functioning may benefit from a delayed care transition and additional parental involvement in order to successfully manage the complex T1DM regimen that the illness requires. Further research is warranted to determine the mechanisms through which parental involvement or monitoring is effective at maintaining adequate treatment compliance and to examine the characteristics of children and adolescents for whom these types of parental involvement are most beneficial.

Parent-adolescent conflict surrounding T1DM care tasks.

The adolescent years are a time prone to increased levels of conflict among adolescents and their parents (Laursen, 1993). Conflict typically occurs with greater frequency and intensity during middle to late adolescence and plays a normative function according to most developmental theories. Intense and sustained conflict among parents and adolescents has been associated with delinquency and oppositional behavioral disorders (Patterson, Capaldi, & Bank, 1991). However, conflict that occurs in a constructive manner within an accepting home environment has been shown to be beneficial for teaching adolescents conflict resolution skills and appropriate affect regulation (Cooper, 1988). During the adolescent years, a primary challenge for youth involves their development of a sense of independence and self-management. This priority for adolescents often becomes an area of conflict between adolescents and their parents, as parents have to decide how much responsibility to abdicate and how much to maintain.

The adolescent years can be a time of increased exposure to a variety of stressors in a youth's life, especially those related to school, peer, and family functioning.

Research has shown that a majority of the conflicts that are experienced by parents and healthy adolescents revolve around everyday issues related to self-care, chores, and other responsibilities (Montemayor & Hanson, 1985). For youth with T1DM, this parent-adolescent stress may be exacerbated due to the tension created by the additional diabetes-related care responsibilities that are shared everyday (Miller-Johnson et al., 1994). Despite the additional stress created by a chronic illness diagnosis, research has demonstrated comparable levels of family conflict with regard to frequency and intensity in homes of healthy adolescents and in homes of adolescents with T1DM (Viikinsalo, Crawford, Kimbrel, Long, & Dashiff, 2005). Although there does not appear to be additional conflict in homes of adolescents with T1DM, there is potentially more serious consequences to the conflict that does occur. A greater frequency of family conflict experienced among parents and adolescents with T1DM has been shown to be related to poorer quality of life, whereas higher family social support has been related to better quality of life and better treatment adherence (Pereira, Berg-Cross, Almeida, & Machado, 2008).

The overall family environment during the adolescent years appears to play a significant role in shaping adolescents' self-care behaviors. Specifically, diabetes-related family conflict has been shown to be one of the best predictors of poor treatment adherence in adolescents with T1DM (Jacobson et al., 1994). Several studies have demonstrated that parent-adolescent conflict is negatively related to youth's metabolic control and positively related to youths' treatment adherence (Anderson et al., 2002; Anderson et al., 2009; Miller-Johnson et al., 1994; Miller & Drotar, 2003). In one study (Miller-Johnson et al., 1994), researchers found a significant association between conflict and treatment adherence/metabolic control, but they failed to find any significant relationships among several other family environment variables, which included parent discipline, parental warmth, or behavioral support and treatment adherence or metabolic control. There is also evidence that the care transition period that occurs during adolescence, as discussed earlier, is also related to diabetes-related family conflict. When adolescents are more independent in their T1DM care tasks, they appear to exhibit higher levels of conflict with their parents (Schilling, Knafl, & Grey, 2006). It is possible that this conflict is due to the negotiation of responsibility sharing that takes place when adolescents begin to take more responsibility, as well as the frustrations that may be experienced as a result of autonomous management. Greater discrepancy of mothers' and adolescents' perceptions of responsibility sharing has also been significantly associated with increased conflict (Miller & Drotar, 2003).

Development of the Adolescent Brain

Along with many of the psychological and social changes that occur throughout the adolescent years, there is increasing evidence that this is also a period of significant cortical development as adolescents experience marked changes in brain regions associated with response inhibition, calibration of risk and reward, and emotion regulation (Steinberg, 2005). Although some of the changes in connectivity within the brain occur simultaneously with the hormonal changes associated with puberty, there is not a perfect relationship among the two (Dahl, 2001). Most of these changes occur within the structures of the developing prefrontal cortex, but there are also connections created from the prefrontal cortex to other regions of the brain. Many of these connections are to the limbic system, which affect the way that adolescents evaluate and react to situations involving risk and reward (Spear, 2000). Research has demonstrated that there are two structural changes that occur in the prefrontal cortex during adolescence (Blakemore & Choudhury, 2006). The first change involves myelination of the neurons within this region of the brain. Myelin serves as insulation for the axons of neurons and acts to speed the transmission of neural impulses by as much as 100 times that of unmyelinated neurons. Although other neurons within the body, such as motor and sensory neurons, become myelinated in the first few years of life, it appears that this process is delayed in the neurons of the prefrontal cortex (Yakovlev & Lecours, 1967). Another developmental change that has been noted to occur within the prefrontal cortex is a process known as synaptogenesis. This process, which is designed to make the brain a more efficient machine, involves the systematic pruning of neural connections. As a result, frequently-used pathways are strengthened and infrequently- used connections are terminated thus eliminating inefficient pathways (Blakemore & Choudhury, 2006; Rakic, Bourgeois, & Goldman-Rakic, 1994).

Extensive cellular research has examined this increased myelination and synaptic proliferation within the neurons of the prefrontal cortex during adolescence. More recently, research using Magnetic Resonance Imaging (MRI) has supported this early work and has demonstrated that when comparing young children to adolescents, there is a higher percentage of white matter (which represents myelination on an MRI scan) in adolescents' prefrontal cortices and a higher percentage of gray matter in the prefrontal cortices of younger children (e.g., Sowell et al., 1999; Sowell et al., 2003). Despite these findings, there remains no clear consensus as to whether these MRI findings are a result of increased myelination, synaptic pruning, or a combination of both of these processes (Paus, 2005).

Longitudinal research examining cortical development among a group of children and adolescents aged 3-15 has also demonstrated a decrease in gray matter from childhood through adolescence in the dorsal frontal cortex (Thompson et al., 2000). This decrease in gray matter and subsequent increase in white matter, as viewed through MRI scans, has also been shown to coincide with the onset of puberty (Giedd et al., 1999). It appears that there are significant changes within the structures of the prefrontal cortex that occur throughout adolescence and increasing evidence that this development may transpire into the mid 20's (Giedd, 2004; Sowell et al., 2001). Giedd (2004) found through a longitudinal study design that the last area of the brain to develop was the dorsal lateral prefrontal cortex (DLPC), which did not fully develop until the early 20's. The DLPC is an area of the brain that is responsible for individuals' abilities to inhibit impulses, strategize, and weigh risk and reward decisions. These cognitive abilities have been studied extensively through imaging and neuropsychological research to further examine how this late neural development affects adolescents' day to day functioning. Some of the areas of cognitive functioning that have been studied include attention, memory, intelligence, and executive functioning.

Development of Executive Functioning

Executive functioning is defined as "a collection of interrelated functions, or processes, which are responsible for goal-directed or future-oriented behavior, and has been referred to as the 'conductor' which controls, organizes, and directs cognitive activity, emotional responses, and behavior" (Anderson, 2008, p. 4). In general, executive functioning involves the processes that are necessary for individuals to develop a goal or plan, execute the plan, and finally, to evaluate the outcome (Luria, 1973). There have been several conceptual models proposed to help explain the functions of the executive system, but none are universally accepted (Anderson, 2008; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Early models proposed that executive functioning was best understood by a unitary concept or "central executive" (Baddeley, 1986). There has been intense debate over whether executive functioning exists as a unitary of multidimensional construct. Much of this controversy has arisen as a result of increasing evidence that individuals rarely display gross executive dysfunction and due to the results of factor analytic studies which have identified multiple factors within executive functioning (Anderson, 2008). There are several models used to understand executive functioning abilities (i.e., Lezak, 1995; Norman & Shallice, 1986; Zelazo, Carter, Reznick, & Frye, 1997). Executive functioning is often measured through various cognitive components or abilities, which include planning and goal setting, generating ideas to solve a problem, initiation, behavioral inhibition, set shifting and cognitive flexibility, and working memory (Niloufar Salimpoor & Desrocher, 2006).

Neuropsychological research examining executive functioning abilities among adolescents has suggested that these abilities may be particularly poor at the beginning of puberty (age 9-12) when the synaptogenesis of neural circuits begins in the prefrontal cortex. Although this process increases the efficiency with which the neurons communicate in the prefrontal cortex over the course of adolescence, this initial proliferation of synapses that occurs at the beginning of puberty appears to have the opposite effect and may lead to worse executive functioning abilities. Following the onset of puberty, executive functioning abilities tend to increase in a linear manner throughout adolescence (McGivern, Andersen, Byrd, Mutter, & Reilly, 2002).

Given that some models of executive functioning examine its various cognitive components, much of the research examining executive functioning has followed suit. When examining the period of preadolescence, there appear to be modest gains in set-shifting, selective attention, and impulsive responding in children as early as ages 8-10, but development of more advanced executive abilities such as working memory and strategic planning showed greater development throughout middle to later adolescence (Klimkeit, Mattingley, Sheppard, Farrow, & Bradshaw, 2004; Luciana & Nelson, 2002). It is possible that the greater cognitive flexibility that comes with adolescence may initially be an encumbrance to adolescents as they are analyzing information to begin a problem solving task. Adolescents often make several errors in their judgments and may overanalyze information as they learn to navigate problem solving tasks with new sets of skills (Anderson, 2002). Consistent with the evolutionary course of development of the entire cortex, the prefrontal cortex appears to follow the same trajectory with simpler skills developing before those that are more complex. Primitive executive skills such as attending and impulse control develop first, and more cognitively advanced skills sets such as strategic planning and prospective memory develop later in adolescence (as reviewed in Anderson, Anderson, Jacobs, & Smith, 2008).

There are multiple ways through which the basic components of executive functioning, as described above, are assessed in research as well as in clinical settings. One method of assessment involves asking individuals about their executive functioning abilities by listing several tasks and assessing the level of difficulty experienced with each. This method usually involves a structured interview or self-reported questionnaire. Another method of assessment involves the use of neuropsychological measures of executive functioning. The primary advantage to the neuropsychological measures is that they provide an objective measure of executive functioning, and they have significantly lower face validity than the interview or questionnaire methods. However, despite the "gold standard" nature of these tests, there are several problems that exist with these measures, which include the multifactorial nature of the tests, issues with the generalizability of the tests to real life situations, and a general lack of sufficient normative samples for many ethnic minority groups (Kinsella, Storey, & Crawford, 2006). Due to these shortcomings, it is recommended that researchers and clinicians utilize a multilevel assessment of executive functioning, which typically involves the use of neuropsychological measures as well as self- and caregiver-report measures. Questionnaire measures of executive functioning offer an advantage in that they assess executive functions in multiple environments such as home and school (Kinsella et al., 2006; Niloufar Salimpoor & Desrocher, 2006). This multilevel assessment method, which includes neuropsychological measurement of several domains of executive functioning as well as questionnaires that provide data from multiple settings, appears to provide the most comprehensive assessment of cognitive functioning (McCloskey, Perkins, & Van Divner, 2009).

Neurocognitive Functioning in Children and Adolescents with T1DM

Given the psychobiological strain that T1DM places on the body through the variability in blood glucose levels, it is worth exploring the effects that the illness has on the cognitive functioning of children and adolescents. As reviewed earlier, adolescence is a period in which treatment adherence and metabolic control among youth with T1DM is particularly poor (e.g. Anderson et al., 1990). Since research has demonstrated that adolescents' executive functioning abilities are the poorest at the beginning of adolescence and slowly develop throughout the teenage years, this may provide some insight into the challenges that adolescents face when beginning to independently manage their T1DM cares (McGivern et al., 2002).

There are many complications to poorly maintained T1DM both in the short and long term. The T1DM treatment regimen is designed to mimic the action of the pancreas through the injection of insulin to lower blood glucose levels from the consumption of carbohydrates. Because of this imperfect science and the estimation that is involved in treatment, the body is subjected to abnormal concentrations of glucose and insulin, which puts a strain on many organs of the body. For children and adolescents, whose brains are still developing, this constant fluctuation of blood glucose levels can cause damage to these developing structures and can cause cognitive impairment. In addition to the constant aberration of blood glucose, individuals with T1DM also experience periods of extreme low blood glucose levels (hypoglycemia) and extreme high blood glucose levels (hyperglycemia), which have been associated with cognitive dysfunction, especially when it is experienced early in life (Desrocher & Rovet, 2004). When compared with children and adolescents without a chronic illness, those with T1DM tend to perform worse on several measures of cognitive performance. A meta-analysis examining studies that included youth with T1DM and healthy controls under the age of 18, revealed that children with T1DM performed moderately worse on measures of attention and executive functioning (Gaudieri et al., 2008). There are several illness-related correlates and demographic characteristics that have been proposed to explain the lower cognitive abilities seen in youth with T1DM which include frequency and severity of hypo- and hyperglycemia and age of T1DM onset (Sansbury, Brown, & Meacham, 1997).

Hypoglycemia is a condition in which blood glucose concentrations fall below 70 mg/dl and individuals experience weakness, dizziness, and confusion and can lose consciousness. It is fairly prevalent among children with T1DM, as there are many ways to become hypoglycemic including taking too much insulin or over-exercising (Beaser, 2007). There are several levels of hypoglycemia that can occur. Asymptomatic and mild hypoglycemia can typically be treated by the individual simply by taking some type of sugar or fast acting carbohydrate. Episodes of the most severe level of hypoglycemia result in a loss of consciousness and can lead to coma. Each year, about 10% of children with T1DM experience the more severe type of hypoglycemia (Barkai, Vamosi, & Lukacs, 1998).

There has been a significant amount of debate over the level and frequency of hypoglycemia that is needed to result in cognitive impairment. Most research has found a significant association among episodes of hypoglycemia and impairments in several cognitive domains such as attention, executive functioning, and memory (Bjorgass, Gimse, Vik, & Sand, 1997; Rovet, Ehrlich, Czuchta, & Akler, 1993; Ryan et al., 1990). However, results from the Diabetes Control and Complications Trial Research Group (DCCT), which conducted a nine-year longitudinal study following 1441 adolescents and adults with T1DM, did not corroborate the finding that frequent hypoglycemia is related to cognitive impairment in youth with T1DM (DCCT, 1994; Musen et al., 2008). These findings have been widely criticized due to the lack of a control group in the study, which makes it difficult to draw conclusions about the effects of hypoglycemia on neuropsychological functioning over a period of time. Additionally, there have been criticisms about some of the neuropsychological measures used in the DCCT. Specifically, most of the neuropsychological measures utilized in the study, other than the measure assessing intelligence, were not normed for individuals under the age of 16, which would likely lead to floor effects for the group of adolescents. Other reasons for this debate regarding the role of hypoglycemia in cognitive dysfunction may stem from how researchers measure hypoglycemic episodes. There is tremendous variability in the severity of hypoglycemia that children experience. For example, some children experience many episodes of the mildest form of hypoglycemia and are not aware that it is even occurring. Other children experience nocturnal hypoglycemia, which also occurs outside of their awareness. For children who are diagnosed with T1DM as infants, only the most severe levels of hypoglycemia can be treated since the milder levels rely on the individual's report (Desrocher & Rovet, 2004). Due to these reasons, it is difficult to study the effects of hypoglycemia on cognitive functioning.

Hyperglycemia is a condition in which individuals have severely high levels of blood glucose that can result from eating high carbohydrate food or not dosing the proper amount of insulin. When individuals experience long durations of hyperglycemia, DKA can occur; this can lead to coma and eventually death if it is not treated (Beaser, 2007). There is evidence that people who experience DKA may suffer damage to their central nervous system and may experience deficits in their cognitive functioning. It has been suggested that recurrent episodes of DKA may impact the myelin formation in specific areas of the developing brain. For adolescents, whose brains are developing most rapidly in the prefrontal cortex, this may affect their cognitive abilities, which typically show marked developments during this period (Rovet & Alverez, 1997).

In general, research has found that acute episodes of hyperglycemia do not have the same deleterious effect on cognitive abilities in the way that episodes of hypoglycemia have been shown to have (Desrocher & Rovet, 2004). One study examining the association between episodes of hyperglycemia and cognitive functioning demonstrated that children who had frequent episodes of hyperglycemia performed poorer on tasks of executive functioning than children who had not experienced as frequent episodes (Kaufman, Epport, Engilman, & Halvorson, 1999). There is also some evidence that multiple episodes of DKA may be related to cognitive dysfunction as well (Lehmkuhl et al., 2009). Perhaps these findings can be explained by the disruption in myelination of neurons in the developing frontal cortex from which the executive functions primarily stem.

One of the most consistent predictors of cognitive dysfunction among children and adolescents with T1DM is the age at which they were diagnosed. Research has consistently demonstrated that early onset of diabetes (which typically means prior to age 7) is associated with several domains of cognitive dysfunction. Specific domains of cognitive functioning that have been shown to be most affected by early onset of the disease include motor speed, memory, and executive functioning (Ferguson, Blane, Wardlaw, Frier, Perros, McCrimmon et al., 2005; Rovet & Alvarez, 1997; Wolters, Yu, Hagen, & Kail, 1996). Gaudieri and colleagues (2008) conducted a meta-analysis examining the cognitive deficits experienced by youth diagnosed with T1DM and found that they were at greater risk than healthy children to develop neurocognitive complications. This study went on to subdivide subjects into those that were diagnosed early in life and those who were not. Results of these further analyses indicated that the cognitive deficits were even greater for those individuals who were diagnosed early in life (i.e. prior to age seven).

It is difficult to determine the mechanisms through which early onset of the illness impacts the cognitive functioning of children. Ryan (2006) hypothesized that the effects are merely a result of hypoglycemia that is not reported or treated due to the age of the children and their inability to acknowledge feelings of hypoglycemic episodes. Prior to age seven the brain is undergoing changes in several areas. According to Ryan's (2006) diathesis hypothesis, these deficits seen in youth diagnosed at an early age are primarily due to chronic hyperglycemia that occurs during these critical periods of development, creating structural and functional changes to the CNS and leaving the brain vulnerable to later insults. In studies examining cognitive dysfunction in children and adolescents with T1DM, the greatest deficits were seen in children who experienced a hyperglycemia-induced seizure prior to age five (Rovet & Alvarez, 1997). It is possible that a seizure experienced early in brain development increases the vulnerability to later brain insults from episodes of hypoglycemia, which has been found to be a consistent predictor of cognitive dysfunction.

Children and adolescents with T1DM appear to be at risk for deficits in several domains of their cognitive functioning which includes executive functioning (Gaudieri et al., 2008). Research has demonstrated that our executive functioning abilities rely heavily on blood glucose as a source of energy, perhaps more than other cognitive functions (Gailliot & Baumeister, 2007). Tasks that require our executive functions have been shown to consume more glucose than tasks that utilize other cognitive abilities (Fairclough & Houston, 2004). There have been many theories examining why executive dysfunction exists among individuals with T1DM, and some consistent correlates have emerged which include episodes of hypoglycemia, episodes of hyperglycemia and DKA, and age of disease onset. Although these correlates are all different, to some degree all of these factors involve an increased vulnerability to the developing brain as a result of the unpredictability in blood glucose levels that are common to individuals with T1DM. Research has come a long way in examining the executive deficits that are found in this population; however, there has been little research exploring the potential behavioral consequences of these deficits.

Executive functioning and T1DM treatment adherence.

The development of decision-making skills and movement towards behavioral autonomy are important tasks of adolescence. For adolescents with T1DM, these tasks have additional salience due to the additional challenges adolescents face as they begin to autonomously manage many of the tasks related to their T1DM diagnosis. Given the deficits in executive functioning that children and adolescents appear to be more susceptible to, decision making competence may be directly related to the poor treatment adherence and metabolic control that is typically seen during adolescence. Several research studies have examined decision making abilities among adolescents with T1DM and have found that poorer decision-making competence is significantly related to poorer treatment adherence and glycemic control (Miller & Drotar, 2007; Wysocki et al., 2008). These studies were cross-sectional designs and relied on self- and parent-report of decision making skills. In another study, adolescents who participated in a six-week problem solving diabetes education program displayed significantly better metabolic control (i.e., lower HbA_{1c} values) and treatment adherence, as indicated by more frequent blood glucose checks, when compared to a control group six months following the intervention (Cook, Herold, Edinin, & Briars, 2002). All of these studies that measured adolescents' problem solving abilities provide further insight into the importance of executive function in managing a chronic illness such as T1DM.

Although this research is important in informing researchers and clinicians about adolescent behavior, there has been little research examining the cognitive functions associated with decision-making among this population. Specifically, executive functioning abilities, which have been shown to be moderately worse in adolescents with T1DM than they are in healthy adolescents, play a significant role in problem solving competency and should be explored in relation to treatment adherence and functional outcome measures such as metabolic control.

Given the complexity of the diabetes treatment regimen, executive functions encompass many of the skills that are needed in order for individuals to successfully manage all of the self-care tasks that they are supposed to maintain. To date, only a few studies have examined the relationship between executive functioning abilities in children and adolescents with T1DM and treatment adherence. Bagner and colleagues (2007) examined this relationship in a sample of children and adolescents diagnosed with T1DM who were ages 8 to 19. More developed executive functioning abilities, as measured by parents' self report questionnaires, were related to better treatment adherence in youth of all ages. This study provides some initial evidence that executive functions play an important role in the illness management of youth with T1DM; however, this study failed to examine a measure of metabolic control. Further, McNally, Rohan, Shroff Pendley, Delamater, & Drotar (2010) examined the associations among executive functioning, adherence, and metabolic control in a sample of children ages 9 to 11. These researchers found that better executive functioning abilities were significantly related to better adherence. Additionally, executive functioning served as a significant mediator in the relationship between treatment adherence and metabolic control. Another research study with a sample of children (ages 9 to 11), using a longitudinal study design over two years found that changes in behavioral regulation predicted changes in adherence but not in glycemic control (Miller et al., 2012). A limitation of these studies is that they exclusively used parent-report measures of youth's executive functioning abilities but did not obtain a youth self-report or performance-based neuropsychological measures of executive functioning.

Integration of Background Research

The adolescent years have been an area of focus in T1DM research due to a preponderance of evidence demonstrating that it is the period of development in which treatment adherence and metabolic control are the poorest (e.g. Anderson et al., 1990). To determine why this period of development is associated with these negative health outcomes, research has focused on several family variables including the amount of parental involvement (e.g. Helgeson et al., 2008), the amount of parental monitoring of T1DM management (e.g. Palmer et al., 2004), and the amount of conflict among parents and adolescents (e.g. Miller-Johnson et al., 1994). All of these factors have been shown to be significant correlates of adolescent illness mismanagement; however, there appears to be a void in the literature with respect to another area of development that occurs during adolescence. Given the complexity involved in managing and planning for a flexible T1DM treatment regimen, advanced cognitive skills are likely necessary to successfully manage the illness. Research examining cognitive development among healthy adolescents has indicated that this developmental process is usually not complete until the mid 20's and, consequently, is partially responsible for the increased risk taking and lack of perspective taking that is common among adolescents (Giedd, 2004; Steinberg, 2005). Adolescents with T1DM face these same biological challenges as healthy adolescents; however, they also experience further developmental complications as a result of their illness. Adolescents with T1DM have been shown to experience deficits in several domains of cognitive functioning, including executive functioning abilities. Although research has demonstrated that children and adolescents with T1DM display moderately worse executive functioning abilities when compared to healthy controls, there has been little research examining the behaviors or functional outcomes associated with these deficits (Gaudieri et al., 2008).

The current study focused on integrating these areas of research to further examine the multifaceted ways in which the family contributes to T1DM management among adolescents while accounting for their executive functioning abilities. Upon careful review of the literature, there does not appear to be any research examining these family variables (i.e. parent involvement, parental monitoring, and family conflict) and cognitive variables (i.e. executive functions) to examine their aggregate contributions towards the prediction of treatment adherence and metabolic control.

Further, these cognitive and family variables were incorporated into proposed moderation models which examined the ways through which executive functioning was related to treatment adherence and metabolic control, while taking into account parental contributions to adolescents' diabetes management. It was hypothesized that the relationship between adolescents' executive functioning and treatment adherence and metabolic control would be moderated by the amount of parental involvement or monitoring of adolescents' T1DM management. Specifically, it was expected that adolescents would be more likely to display poor adherence to their T1DM treatment regimen (and consequently worse metabolic control) when they are handed the responsibilities for autonomous management too early in their development when they do not possess the proper executive functioning abilities, especially in an environment in which they are not properly supervised. Figure 1 depicts this proposed moderation model.

The aims of the present study were as follows:

I. To examine whether adolescents' executive functioning abilities were related to treatment adherence (i.e., replicating results of Bagner et al., 2007) and metabolic control.

II. To examine the amount of variance that executive functioning accounted for in predicting adolescents' treatment adherence and metabolic control beyond the contributions of family variables (i.e., parental involvement of T1DM management, parental monitoring of T1DM management, parent-adolescent conflict).

III. To examine the role of parental monitoring and parental involvement in T1DM care in moderating the relationship between adolescents' executive functioning and treatment adherence and metabolic control.

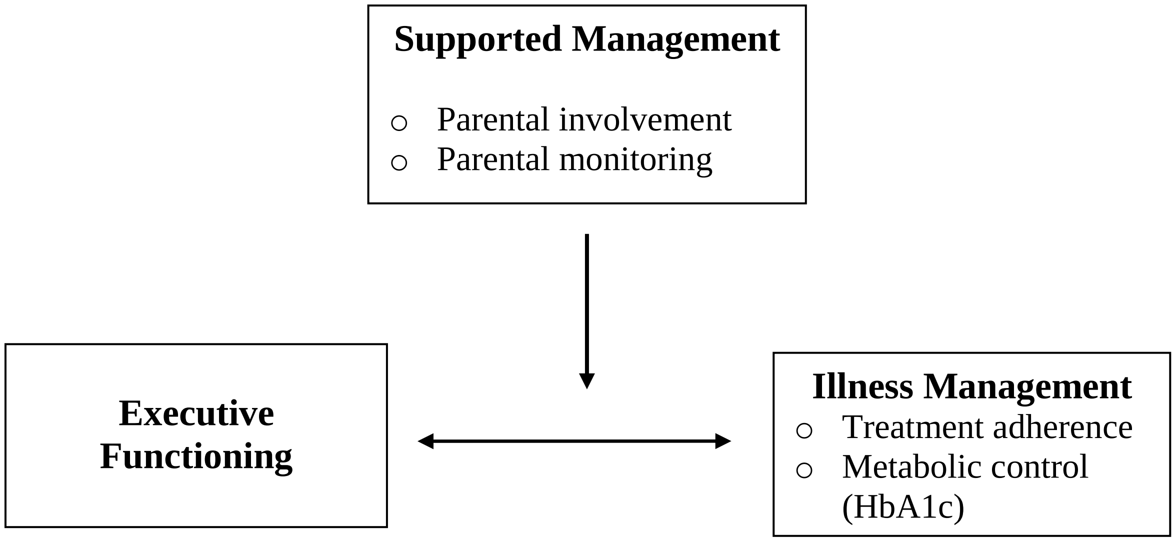

Figure 1. Proposed model examining relationships among factors influential in adolescent illness management

The hypotheses that were tested in the current study were as follows:

Ia Adolescents' **executive functioning** abilities (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS scores and WCST scores) would be positively correlated with **treatment adherence** (i.e., SCI scores and total BG checks).

Ib. Adolescents' **executive functioning** abilities (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) would be negatively correlated with **metabolic control** (i.e., HbA_{1c} values).

IIa Adolescents' **executive functioning** abilities (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) would account for a significant percentage of variance in predicting adolescents' **treatment adherence** (i.e., SCI scores) beyond the contributions of familial variables, including **T1DM related conflict** (i.e., DFCS total score) and the amount of **parental involvement** and **parental monitoring** of T1DM management (i.e., DFRQ and PMDC total scores).

IIb. Adolescents' **executive functioning** abilities (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) would account for a significant percentage of variance in predicting adolescents' **metabolic control** (i.e., HbA_{1c}) beyond the contributions of familial variables, including **T1DM related conflict** (i.e., DFCS total score) and the amount of **parental involvement** and **parental monitoring** of T1DM management (i.e., DFRQ and PMDC total scores).

IIIa. The amount of **parental involvement** in adolescents' T1DM management would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **treatment adherence** (i.e., SCI scores).

IIIb. The amount of **parental monitoring** of adolescents' T1DM management would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **treatment adherence** (i.e., SCI scores).

IIIc. The combined contribution of **parental involvement and monitoring** (i.e. composite score of DFRQ and PMDC total scores) would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **treatment adherence** (i.e., SCI scores).

IIId. The amount of **parental involvement** in adolescents' T1DM management would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **metabolic control** (i.e., HbA_{1c}).

IIIe. The amount of **parental monitoring** of adolescents' T1DM management would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **metabolic control** (i.e., HbA_{1c}).

IIIf. The combined contribution of **parental involvement and monitoring** (i.e. composite score of DFRQ and PMDC total scores) would moderate the relationship between adolescents' **executive functioning** (i.e., parent and adolescent reported BRIEF and adolescents' D-KEFS and WCST scores) and **metabolic control** (i.e., HbA_{1c}).

Research Methods and Design

Participants

Eligible participants in the current study included adolescents, age 12 to 18, who had been diagnosed with T1DM at least six months prior to their participation in the study. This length of diagnosis criterion is typical for studies examining children with T1DM and is thought to provide the adolescent and family a sufficient amount of time to adjust to the treatment demands the illness often requires. For adolescents to be enrolled in the study, at least one of their parents had to agree to participate. In order to participate in the present study, parents and adolescents had to be able to speak English, and adolescents could not be diagnosed with other chronic medical conditions requiring an additional treatment regimen. Participants were recruited from the Children's Hospital of Wisconsin (CHW) diabetes clinic.

Procedures

The recruitment of participants occurred through the following three methods:

- One form of recruitment consisted of mailing letters explaining the study to eligible participants. Potential participants were sent a postcard to return to the researchers indicating whether they were interested in participating in the study or not.
- Another method of participant recruitment involved making phone calls to families who had previously agreed to be a part of the Registry Project (RP) in the diabetes clinic at CHW. Psychologists at CHW developed the RP to make recruitment for behavioral

health research projects in the diabetes clinic more direct for families who were interested in taking part in research. Families who had signed up for the project agreed to be directly contacted (by telephone or mail) to learn about studies taking place in the clinic for which they may be eligible.

- Another method of recruitment involved speaking with families in the diabetes clinic at CHW when they arrived for their regularly scheduled appointment. Interested families usually participated in the protocol following their appointment that day.

The three recruitment methods outlined above were conducted concurrently; however, attention was given to ensure that families were not contacted through multiple methods. Following recruitment, most families who were interested in participating took part in the research project either prior to or following their regularly scheduled clinic appointment; however, some families scheduled a time to participate that was independent of their diabetes appointments. If both parents attended the appointment, each parent completed the relevant questionnaires; however, it was more likely that one parent was present. In these situations, a packet of study materials (i.e., consent forms and questionnaires) and a self-addressed, postage-paid envelope was sent home for the other parent to complete. If these forms were not returned within two weeks of the clinic appointment, a follow-up phone call was placed to the family.

Parents and adolescents completed consent, assent, and Health Insurance Portability and Accountability Act (HIPAA) forms. Following the consent procedure, parents and adolescents completed the questionnaires, as outlined in the subsequent section. Once the adolescents completed the self-report measures, they were administered the performance-based, neuropsychological measures.

Prior to their participation in the study, adolescents were asked to test their blood glucose values via finger prick testing using their personal meter. If participants had readings that were below 75mg/dl, they were given a fast acting carbohydrate snack to bring their blood glucose levels into their target range (with an expected range for adolescents from about 90mg/dl to 150mg/dl; Bismuth & Laffel, 2007). Following a 15-minute break, participants were asked to recheck their blood glucose levels, and the study protocol resumed if their blood glucose value was above 90mg/dl. This procedure was important because low blood sugars have been associated with sluggish cognitive tempo and research has demonstrated that executive functioning abilities are reliant on blood glucose (Beaser, 2007; Gailliot & Baumeister, 2007).

The current study took about one hour to complete, and each family was compensated with a $20.00 gift card to Target for their participation. Approval was obtained from the Institutional Review Boards (IRB) at CHW and at Marquette University.

Measures

Parent demographic questionnaire (Parent report)

Parents completed a demographic questionnaire, which included basic demographic and illness-related information about the family and youth. More specifically, it asked about parents' personal information (e.g. occupation, education, annual income, ethnicity, marital status, custody arrangements of adolescent) as well as information about the adolescent with T1DM (e.g. length of T1DM diagnosis, number of

T1DM-related hospitalizations and clinic appointments, and additional medical diagnoses).

Self-Care Inventory-Revised version (SCI-R; Parent and Adolescent report)

The SCI-R is a self-report questionnaire that measures adherence to care behaviors that are associated with diabetes (La Greca & Bearman, 2003; Weinger, Butler, Welch, & La Greca, 2005). It is comprised of 15 items that measure participants' reported adherence of self or child in relation to a diabetes regimen over the previous two weeks. The items measure various aspects of care including blood glucose monitoring, insulin injections, and maintenance of the prescribed diet and exercise recommendations of their physician. Participants respond to each item on a five-point Likert scale that ranges from 1=*complete nonadherence* to 5= *complete adherence*. The SCI-R was scored by calculating the mean of all the items and converting it to a 0 to 100-point scale. Higher scores on the SCI-R indicate a greater level of adherence (Weinger et al., 2005).

The SCI-R has been shown to be a reliable and valid measure of treatment adherence for children and adolescents with diabetes. Adequate test-retest reliability has been demonstrated (Lewin et al., 2009). There was evidence of good internal consistency in the current study for parents' reports (α = .81) and for adolescents' reports (α = .77). The SCI-R scores have been highly correlated with other measures of adherence, including a 24-hour recall interview and structured interview (Diabetes Self-management Profile; Greco et al., 1990; Harris et al., 2000; Lewin et al., 2009).

Diabetes Family Responsibility Questionnaire (DFRQ; Parent and Adolescent report)

The DFRQ is a 17-item questionnaire that assesses how adolescents and their parents divide or share several tasks that are associated with adolescents' diabetes care. There are three factors underlying the items in this measure that include responsibilities related to regimen tasks, general health maintenance, and social presentation of diabetes. For each item the participant is asked to indicate whether the (1) Parent(s) take responsibility for this task almost all of the time, (2) Parent(s) and child share responsibility for this task about equally, or (3) Child takes or initiates responsibility for this task almost all of the time (Anderson et al., 1990). The DFRQ is scored by summing the items with higher scores representing a greater amount of autonomous management by the youth (Anderson et al., 1990)

The current study found this measure to have acceptable internal consistency for parent ($\alpha = .84$) and child ($\alpha = .78$) report. The DFRQ has also demonstrated acceptable levels of concurrent validity in prior research with the Independence Subscale on the Moos Family Environment scale (Moos, 1986; $r = .21$, $p < .05$)

Parental Monitoring of Diabetes Care Scale (PMDC; Parent and Adolescent report)

The PMDC (Ellis et al., 2007) assesses how frequently parents monitor numerous aspects of their adolescents' diabetes management regimen. In separate parent and adolescent versions of the measure, respondents answer 18 questions and indicate how frequently parents monitored behavior during the past month. Items are answered on a five-point Likert scale (e.g., "More than once a day," "Once a day," "Several times a week," "Once a week," and "Less than once a week"). The five domains of monitoring measured by the PMDC include Availability of Medical Supplies/Devices, Monitoring of

Blood Glucose Checking, Oversight of Diet, Monitoring of Nonadherence, and Direct Oversight of Diabetes Management Behaviors. The present analyses utilized a Total Monitoring Score, which is calculated by summing all items on the scale. Scores can range from 18-90 with higher numbers representing higher levels of parental monitoring.

In the present study there was evidence of adequate internal consistency for the total score with Cronbach's alphas of .87 for the parent-report and .88 for the adolescent-report versions. Previous research has demonstrated that parental monitoring as assessed using the PMDC accounted for a significant amount of variance in predicting adolescent diabetes management and had a significant indirect effect on metabolic control (Ellis et al., 2007).

Diabetes Family Conflict Scale (DFCS; Parent and adolescent report)

The DFCS (Hood, Butler, Anderson, & Laffel, 2007) is a parent- and youth-report questionnaire of the negative emotions that often surround several aspects of the diabetes treatment regimen. The domains that are measured include blood-glucose monitoring, quality of life, and perceived parental burden from diabetes management. Individuals are asked to respond on a three-point Likert scale (1= never argue, 2= sometimes argue, and 3= always argue) indicating how much they have argued with their parent/adolescent about several diabetes-related tasks. The measure is scored by summing all of the items, which yields a total conflict score ranging from 19 to 57, with higher numbers representing a greater amount of conflict (Hood et al., 2007).

The DFCS was shown to have acceptable internal consistency in the present study for both parent (α= .87) and adolescent (α= .94) responses. Previous research has also demonstrated excellent concurrent validity with measures of quality of life and negative affect surrounding blood glucose monitoring (Hood et al., 2007). In addition, the DFCS has demonstrated adequate predictive validity, as measured by significant correlations between family conflict scores and youths' HbA_{1c} values for child's report and parent's report of conflict (Hood et al., 2007).

Measures of Cognitive Functioning

Behavior Rating Inventory of Executive Functioning (BRIEF; Parent report)

The BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000) is a parent-report measure of children's and adolescents' executive functioning. The measure consists of 86 items that are designed to assess youths' abilities to complete tasks which rely on several domains of executive functioning. The measure consists of eight clinical scales and two validity scales. These domains include abilities related to problem solving flexibility (Shift scale), anticipation of future events and setting goals (Plan/Organize scale), controlling impulses (Inhibit scale), modulation of emotional responses (Emotional Control scale), starting a task (Initiate scale), retaining information in one's mind and following through to complete a task (Working Memory scale), keeping materials orderly (Organization of Materials scale), and assessing performance during or following a task (Monitor scale). The individual scales have been organized into three indices which include the Behavior Regulation Index (BRI; Inhibit, Shift, and Emotional Control scales), the Metacognition Index (MI; Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor scales), and the Global Executive Composite (GEC), which is derived from the two aforementioned indices and represents a total executive functioning score (Gioia et al., 2000). All of the BRIEF subscale scores were examined in bivariate analyses, and those correlations are presented in tables. The BRIEF GEC was used in the multivariate analyses. Higher scores on the BRIEF represent greater levels of executive dysfunction.

The measure includes a list of statements that describes children's behaviors, and parents are asked to indicate how frequently these behaviors are a problem for their child on a three-point Likert scale (Never, Sometimes, Often). Research has demonstrated that the BRIEF is a reliable instrument with internal consistencies ranging from .80 - .98 (Gioia et al., 2000). The present study found the BRIEF Global Executive Composite score to have excellent internal consistency (α= .96). Validity data has indicated that the measure provides consistent findings when compared with other ratings of children's behavior, including the Child Behavior Checklist and Connors Rating Scale (Gioia et al., 2000).

Behavior Rating Inventory of Executive Functioning- Self-report version (BRIEF-SR, Adolescent report)

The BRIEF-SR (Guy, Isquith, & Gioia, 2004) is an adolescent-report measure of executive functioning for youth age 11 to 18. The measure consists of 80 items that are designed to assess the youth's abilities to complete tasks which rely on several domains of executive functioning. The scales and indices for the BRIEF-SR are similar to those of the BRIEF. The measure includes a list of statements that describes several behaviors, and adolescents are asked to indicate how frequently these behaviors are a problem on a three-point Likert scale (Never, Sometimes, Often). Higher scores on this measure represent greater levels of executive dysfunction. Research has demonstrated that the BRIEF-SR is a reliable instrument with internal consistencies ranging from .72 - .96

(Guy et al., 2004). The present study found the BRIEF-SR GEC score to have excellent internal consistency (α= .94). Validity data has indicated that the results of the BRIEF-SR were moderately correlated with parent ratings from the BRIEF (Walker & D'Amato, 2006).

Delis-Kaplan Executive Functioning System (D-KEFS; Adolescent report)

The D-KEFS (Delis, Kaplan, & Kramer, 2001a) is a well-validated neuropsychological assessment tool that is designed to measure various components of executive functions in children and adults. The subtests of the D-KEFS include Trail making Test (TMT), Verbal Fluency Test (VFT), Design Fluency Test (DFT), Sorting Test (ST), Color-Word Interference Test (CWIT), Twenty Questions Test (TQT), Tower Test (TT), Word-Context Test (WCT), and the Proverb Test (PT). The tests are presented to the participant in a game-like manner. Each subtest gives a primary achievement score that is normed based on the individual's age, yielding a scaled score with a mean of 10 and a standard deviation of 3 (Delis, et al., 2001a). In the current study, the TT, VFT, and TMT were administered to participants.

The TT is a similar task to an older executive functioning test, the Tower of London (Shallice, 1982). The TT involves a wooden board with three pegs and five disks of varying sizes. The participant is asked to move the discs, following a set of rules, from one peg to the next, to replicate the configuration displayed in a picture. Fundamental abilities that are assessed by this task include several aspects of goal-directed behavior such as spatial planning, rule learning, self-guided action, inhibition of responses, and maintenance of an instructional set (Delis, et al., 2001a).

The VFT is very comparable to the Controlled Oral Word Association Test (COWAT; Benton, Hamsher, & Sivan, 1994) and is similarly comprised of two conditions, which include letter and category fluency tasks. Participants are asked to state as many words that begin with a specified letter as they can in a 60-second interval. They are then given a category and are asked to state as many words that fall into that category as they can think of. The task is scored by measuring the number of words generated, the number of incorrect responses, and the number of perseverative responses. Fundamental components of executive functioning that are measured with the VFT include cognitive flexibility and working memory (Delis, et al., 2001a).

A final task from the D-KEFS battery that was administered to participants is the TMT. The TMT is a classic executive functioning task that requires participants to draw lines from a variety of visual stimuli while following a meaningful pattern. In one condition, individuals are asked to draw a line from one number to another in numerical order, and in another condition, they are asked to connect letters and numbers in alternating numeric and alphabetic order. Achievement scores for this test are derived from the total completion time for each task. The TMT measures visual scanning and attention as well as flexibility of thinking and working memory (Delis, et al., 2001a).

The reliability of all nine subtests has been shown to be satisfactory with internal consistencies ranging from .62 - .90 across all age groups. The subtests have also been shown to be significantly correlated with several other well established tests of executive functioning, including the California Verbal Learning Test and the Wisconsin Card Sorting Task (Delis, Kaplan, & Kramer, 2001b). Other research has demonstrated that the tests of the D-KEFS are sensitive to the deficits of executive functioning in populations with frontal-lobe injury (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001).

Wisconsin Card Sorting Task (WCST; Adolescent report)

The WCST (Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is a measure used to assess the ability to form abstract concepts, to shift and maintain set, and to utilize feedback. It is designed for use with children and adults aged 5 to 89 years. Participants are asked to sort a group of cards based on three criteria (i.e., color, form, and number) without any explicit directions. Throughout the test, the sorting criterion changes, and participants are measured in their ability to fluidly modify their mental sets in accordance with the changing rules. The test provides information on several aspects of problem solving behavior and includes indices such as number of perseverative errors, failure to maintain set, and the number of categories achieved. The WCST has demonstrated excellent interscorer reliability with interclass correlations above .83 (Axelrod, Goldman, & Woodward, 1992), and it has also been shown to be a valid measure of executive functioning. There is evidence that impairment on the WCST is associated with difficulties in real-world activities among children and adolescents with a traumatic brain injury (Levin et al., 1997) as well as difficulties with goal-directed behavior among youth diagnosed with attention deficit hyperactivity disorder (ADHD; Meyer et al., 2004).

Rationale for Inclusion of Intelligence and Memory Measure

Intelligence and memory were assessed in the current study in addition to executive functioning to further explore whether any relationships that exist among adolescents' cognitive functioning and the T1DM- or family-related variables were truly due to their executive functioning and not their intelligence and/or memory functioning. Although intelligence, memory, and executive functioning are all cognitive functions, research has demonstrated that there is evidence of them being relatively distinct constructs. Early research examining cognitive functioning provided evidence that individuals who underwent dorsolateral frontal lobectemies tended to display gross executive deficits, but they experienced relatively few deficits in Intelligence Quotient (IQ) scores (Milner, 1982). Ardila and colleagues (2000) demonstrated that in a sample of 13 to 16 year-old adolescents, WISC-R scores were not correlated with most measures of executive functioning. The only significant correlations that emerged were between Verbal Fluency scores and Verbal IQ and Full Scale IQ (FSIQ) scores. From these studies it appears that intelligence tests are not sensitive to frontal lobe deficits which are better measured by tests of executive functioning.

Research has also demonstrated an association between some aspects of memory and executive functioning. A study examining the relationship between executive functioning abilities and measures of verbal and visual memory suggested that these constructs shared about 55% of variance. Although this represents a significant amount of shared variance between the two constructs, this finding is not altogether surprising given the important role that working memory plays in mediating executive functioning abilities (Duff, Schoenberg, Scott, & Adams, 2005). Given that there is some overlap between intelligence, memory, and EF abilities, participants in the present study were administered brief measures of their intellectual functioning and visual memory. Although the study hypotheses primarily examined EF abilities, these other cognitive constructs were assessed to further explore the role that adolescents' intelligence and memory may play in diabetes management.

Wechsler Abbreviated Intelligence Scale (WASI; Adolescent Report)

The WASI (Wechsler, 1999) is an abbreviated measure of intelligence that was created to be a quick and reliable screening instrument. It is designed for use with children and adults aged 6 to 89 years. The measure consists of four subtests which include Vocabulary, Similarities, Matrix Reasoning, and Block Design. To administer the full battery, all four subtests are given; however, the abbreviated version consists of two subtests. The two subtest abbreviated form of the WASI, which was administered in the present study, consists of the Vocabulary and Matrix Reasoning subtests. To score the WASI, the total number of items correct for each subtest is converted to a T-score (M = 50; SD = 10) that is normed based on the individual's age. The two subtest T-scores are then summed and converted into a Full Scale Intelligence Quotient (FSIQ) score (Wechsler, 1999).

The Vocabulary subtest consists of 42 items that require the individual to orally define a picture or word. Items 1-4 are scored 0 or 1 points and consist of pictures that the individual must identify. The remaining items are words that are presented to the participant both orally and visually. These items are scored from zero to two points, and the individual must give a definition for each word. Vocabulary provides a measure of individuals' expressive vocabulary, verbal knowledge, and fund of information and also is thought to be a good measure of crystallized intelligence. The Matrix Reasoning subtest is comprised of 35 items. This subtest requires the individual to carefully examine a picture of an incomplete design and select one of five choices indicating which piece completes the design. Matrix Reasoning measures an individual's nonverbal fluid reasoning and general intellectual ability (Wechsler, 1999).

The WASI has demonstrated good reliability coefficients for each of the subtests among a sample of adolescents, including Vocabulary (.86 - .93) and Matrix Reasoning (.86 - .94) as well as for the FSIQ score for the abbreviated battery (.92 - .95), which suggests that the subtests and total scores are generally free from measurement error. Test-retest reliability among an adolescent sample has also been demonstrated to be acceptable for FSIQ scores ($r = .87$). The WASI has also been shown to be a valid measure of intelligence, as demonstrated by significant associations with scores on the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991; Wechsler, 1999).

Rey-Osterrieth Complex Figure (ROCF; Adolescent report)

The ROCF (Meyers & Meyers, 1996) is a measure used to assess visual-spatial constructional ability and visual memory in individuals aged 6 to 93 years. Participants are shown a picture of the complex figure, and they are asked to copy the picture on a blank sheet of paper. Participants are then given 3-minute and 30-minute delayed recall tasks in which they are asked to recreate the picture on another sheet of paper without the stimulus card present. During the delay intervals participants can complete other tasks as long as they are different than the ROCF and do not involve drawing. The measures of performance on the ROCF were derived from copy and delay scores which reflect the accuracy of the original copy and provide an assessment of visual-constructional ability and memory. In the present study, the ROCF was scored using the Meyers & Meyers (1996) scoring system. Each participant's responses were coded by two independent research assistants who met regularly to develop consensus scores for all conditions.

The ROCF has been demonstrated to be a reliable measure with test-retest reliabilities of .76 for the immediate recall task and .89 for the 30-minute delayed recall over a 6-month period (Meyers & Meyers, 1995). It also has been shown to be a valid measure of memory as demonstrated by significant associations with scores on the Token Test (Meyers & Meyers, 1995).

Medical Record Data

Measure of metabolic control (HbA_{1c}).

Metabolic control was indexed by obtaining the HbA_{1c} values from the participants' medical records from the most recent diabetes clinic visit. The HbA_{1c} was determined using the Bayer DCA 2000 instrument (Bayer Diagnostics Inc, Tarrytown, NY). HbA_{1c} reflects the average level of blood glucose control the individual has maintained over the previous 6-8 weeks. Higher numbers reflect poorer control. The average healthy individual has an HbA_{1c} value of less than 6.5%, but this is usually higher in individuals with diabetes, who aim to maintain a value less than or equal to 7.4% (American Diabetes Association, 2008).

Blood glucose monitoring data.

At each clinic appointment, families were asked to bring in adolescents' blood glucose test results from the previous two weeks. From this data we examined the frequency with which adolescents tested their blood glucose levels and calculated a mean number of checks per day value. Research has demonstrated that the frequency of blood glucose tests is highly correlated with levels of metabolic control (Levine, Anderson, Butler, Brackett, & Laffel, 2001).

Results

Data Analytic Plan

The distributions of scores were assessed for skewness and kurtosis, and transformations were conducted as needed (Tabachnick & Fidell, 2007). Due to significant skewness, DFRQ parent and youth involvement scores were transformed using square root transformations. DFCS parent and youth reported diabetes conflict scores and the following BRIEF parent and BRIEF-SR youth reported scores were logarithmically transformed to approximate normal distributions: BRIEF and BRIEF-SR Planning/Organization and Behavioral Regulation Index scores and the Global Executive Composite score from the BRIEF-SR. Additionally, the following variables from the D-KEFS Trail Making Task were reflected and logarithmically transformed: primary scores (amount of time) for the Visual Scanning, Number Sequencing, Letter Sequencing, Number/Letter Sequencing, and Motor Speed tasks. The only other neuropsychological score that was transformed was the Failure to Maintain Set score on the WCST; this variable was also reflected and logarithmically transformed.

The analyses of the first set of hypotheses exploring relationships among executive functioning, treatment adherence, and metabolic control variables were conducted using Spearman correlations. The second set of hypotheses examining which variables were significant predictors of adolescent treatment adherence and metabolic control were conducted using hierarchical multiple regressions. Analyses examining moderations were done using the method proposed by Baron and Kenney (1986) to determine if parental involvement and parental monitoring of T1DM management moderated the relationship between adolescents' executive functioning and treatment adherence and metabolic control. Moderations were conducted examining parental involvement and parental monitoring separately as well as with an aggregate, "Overall Parental Contributions" variable. This variable was created by converting the total scores from the DFRQ and PMDC to z-scores and then summing them into one combined score which reflects the amount of parental oversight and instrumental involvement they may provide in assisting adolescents with their diabetes care.

Bivariate correlations involving variables from the BRIEF, BRIEF-SR, and the performance-based neuropsychological tests were examined using both raw test data and age-adjusted scaled scores or t-scores. Examination of correlations with each of these types of data and the outcome variables yielded few differences in the strength or direction of these relationships. This would suggest that there was sufficient variability among the age-adjusted scores, which would be expected given that the abilities being assessed in the study tend to develop across adolescence. Correlations with raw and age-adjusted data are presented in tables throughout this manuscript; however, the age-adjusted scaled or t-scores are described in text and were used in the multivariate analyses.

Descriptive Analysis

Analyses were based on the full sample of 84 participants, with the exception of adolescents' blood glucose record data (n = 61). The most common reason that families gave for this missing data was that they forgot to bring their log books to the study appointment or the adolescents indicated that they did not keep such records. Parents and adolescents who attended the study protocol appointment completed the questionnaires and/or neuropsychological measures, and participation took about 90 minutes. If one parent was not present at the appointment, the family was asked to take a parallel set of consent forms and questionnaires to the other parent. In total, 129 parents (81 mothers; 48 fathers) completed the study protocol. For the present analyses, data was used from the parent who self-identified and/or was identified by the other parent as the "Primary Diabetes Caregiver."

Descriptive statistics for the primary diabetes caregiver's demographic characteristics are displayed in Table 1. There was a wide variability in the ages of parents with a range of 31 to 74 years. The sample of parents was predominately Caucasian (90.4%), well educated (i.e., 60% had at least a 4-year college degree), and relatively affluent (i.e., 48% reported earning at least $91,000). As expected, and consistent with previous research, most of the parents identified as the primary diabetes caregiver were mothers (n = 77; 91.7%). Seven fathers were identified as the primary diabetes caregivers (7.3%).

Descriptive statistics for the adolescents' demographic characteristics are displayed in Table 2. The sample of adolescents consisted of slightly more males than females (45 males; 39 females) with a mean age of 14.27 years (SD = 1.78; range = 12-18). The majority of adolescents participating in the study were Caucasian (86.9%). There was sufficient variability among HbA_{1c} values (M = 8.39; SD = 1.67) with a range in values of 5.8% to 14%, with higher values representing poorer metabolic control. Adolescents' mean length of diagnosis was 5.95 years (SD = 3.67), and 69% of participants dosed and administered their insulin via syringes or insulin pens, rather than

Table 1. Primary Diabetes Caregiver Demographic Characteristics

	Mean	SD	Range	n	%
Age (years)	45.94	6.67	31 - 74		
Sex					
Female				77	91.7
Male				7	7.3
Ethnicity					
Caucasian				75	90.4
African American				6	7.2
Latino/Hispanic				1	1.2
Other				1	1.2
Family Income					
Less than $30,000				9	11.1
$31,000 - $60,000				14	17.3
$61,000 – $90,000				19	23.5
$91,000 - $120,000				20	24.7
$121,000 - $150,000				7	8.6
Greater than $150,000				12	14.8
Education					
High School Education				11	13
Trade School/2-year College Degree				23	27.4
≥ 4-year College Degree				50	59.6

Table 2. Adolescent Demographic Characteristics

	Mean	SD	Range	%
Age (years)	14.27	1.78	12-18	
Sex				
Female				46.4
Male				53.6
Ethnicity				
Caucasian				86.9
African American				4.8
Latino/Hispanic				2.4
Asian American				1.2
Biracial				2.4
Other				1.2
Diabetes Related Information				
Length of Diabetes Diagnosis (years)	5.95	3.87	.67 – 15.75	
Age of Diagnosis (years)	8.36	3.99	1.10 – 17.00	
Most recent metabolic control (HbA1c) value	8.39	1.67	5.80 – 14.00	
Average number of blood glucose checks/day	4.94	2.19	1.93 – 11.86	
Adolescents who receive insulin via pump				30.9

with insulin pumps. Given the strong relationship between attentional capacity and executive functions (Barkley & Murphy, 2011), parents were asked on the demographics form to note whether their adolescent participating in the study had a preexisting diagnosis of ADHD. In total, eight youth (9.5%) were identified as having a diagnosis of ADHD.

Prior to participation in the study, adolescents were asked to check their blood glucose values via finger prick testing using their personal meter to ensure that they were within the expected range (90mg/dl to 150mg/dl; Bismuth & Laffel, 2007). Adolescents had mean blood glucose values of 162.86 mg/dl (SD = 87.20), and about half of participating adolescents (48%) had blood glucose readings that were outside of the normative range; these participants made dietary adjustments or administered insulin and retested themselves to ensure that their blood glucose was in the expected range (follow-up blood glucose tests: M = 146.38 mg/dl; SD = 31.08).

The descriptive data for the questionnaires are presented in Table 3 and neuropsychological data are presented in Tables 4 and 5.

Preliminary Analysis

Preliminary analyses were conducted using parametric (t-test and ANOVA) and nonparametric (Mann-Whitney U Test) statistical analyses to explore potential relationships among the demographic and diabetes-related variables (i.e., age, sex, race/ethnicity, income, length of time with T1DM, type of insulin administration) and the study variables to identify potential covariates. There were five general demographic covariates (i.e., adolescent age, sex, ethnicity, family income, and diagnosis of ADHD)

Table 3. Means, Standard Deviations, and Ranges For Self-Report Measures

Variable	Mean	SD	Range
Parental Involvement (DFRQ)			
Parent	35.15	5.03	23 - 49
Adolescent	37.63	4.78	25 - 47
Parental Monitoring (PMDC)			
Parent	62.22	13.98	37 - 89
Adolescent	66.42	13.26	36 - 89
Diabetes-Related Conflict (DFCS)			
Parent	24.74	5.47	18 - 49
Adolescent	26.22	8.31	19 - 52
Treatment Adherence (SCI-R)			
Parent	70.74	13.31	40 – 96.67
Adolescent	75.28	12.32	40 – 100
BRIEF (Parent report; T-scores)			
Metacognition Index Score	52.78	10.43	36 – 82
Behavioral Regulation Index	49.98	9.49	36 – 77
Global Executive Composite	51.63	9.83	35 – 82
BRIEF-SR (Adolescent report; T-scores)			
Metacognition Index Score	47.44	10.26	21 – 78
Behavioral Regulation Index	46.94	10.29	26 – 82
Global Executive Composite	47.01	10.51	23 - 83

Table 4. Means, Standard Deviations, and Ranges for Subtests from the D-KEFS

Variable	Mean	SD	Range
Wisconsin Card Sorting Task			
Total Items Administered (raw score)	99.96	21.09	70 – 128
Categories Completed (raw score)	5.39	1.29	0 – 6
Failure to Maintain Set (raw score)	.74	1.06	0 – 5
Perseverative Errors (T-score)	54.25	11.87	28 – 80
Non-Perseverative Errors (T-score)	53.94	10.80	25 – 73
Rey-Osterrieth Complex Figure			
Copy score (T-score)	29.83	11.09	17 – 61.5
Delay score (T-score)	39.67	12.64	19 – 68
Wechsler Abbreviated Scale of Intelligence			
Full Scale IQ (FSIQ; standard score)	99.17	11.76	55 – 130

Table 5. Means, Standard Deviations, and Ranges for Neuropsychological Measures of Executive Functioning, Intelligence, and Memory

Variable	Mean	SD	Range
D-KEFS Trail Making Task (scaled scores)			
Visual Scanning	11.32	2.30	1 - 15
Number Sequencing	9.90	3.05	1 - 14
Letter Sequencing	10.57	2.40	1 – 15
Number-Letter Sequencing	9.36	3.14	1 – 14
Motor Speed	9.15	3.44	1 -14
D-KEFS Verbal Fluency Task (scaled scores)			
Letter Fluency Total Score	9.48	3.02	1 - 16
Category Fluency Total Score	10.07	3.38	1 - 19
Category Switching Total Score	10.25	3.48	2 - 19
Percent Set Loss Errors	11.63	2.04	1 - 13
Percent Repetition Errors	10.05	3.23	1 -13
D-KEFS Tower Task (scaled scores)			
Total Achievement	9.92	2.15	1 - 15
Move accuracy	9.24	2.71	1 - 15

and two diabetes-related covariates (i.e., length of diagnosis and type of insulin administration) that emerged from this analysis.

General demographic covariates.

Adolescent age was significantly related to the number of blood glucose checks, $r = -.39$, $p < .01$, and youth-reported treatment adherence, $r = -.25$, $p < .05$. Further, both parents, $r = -.28$, $p < .05$, and adolescents, $r = -.56$, $p < .01$, reported lower levels of parental monitoring of diabetes care for older adolescents. Examination of a measure of parental involvement in diabetes care revealed similar results with both parents, $r = .61$, $p < .01$, and adolescents, $r = .66$, $p < .01$, indicating greater autonomy of care for older adolescents. On neuropsychological measures, adolescent age was significantly related to the D-KEFS Trail Making Test Visual Scanning, $r = .27$, $p < .05$, and Tower Task Move Accuracy, $r = .35$, $p < .05$, scores.

There were significant differences between boys and girls for parents' reports of their involvement in adolescents' diabetes care, $t(82) = -2.56$; $p < .05$, with parents noting greater autonomy of care for girls compared to boys. Similar to the findings for adolescent age, there were also significant differences based on adolescent's sex for the D-KEFS Trail Making Test Visual Scanning, $t(82) = -2.08$; $p < .05$, and Tower Task Move Accuracy, $t(82) = -2.11$; $p < .05$, scores, which indicated that girls had better developed executive functions than boys in the areas assessed by these measures.

Due to the racially homogenous nature of the sample, we dichotomized the data (i.e. Caucasian vs. Non-Caucasian) for the purposes of analyses to examine possible differences in variables of interest by racial/ethnic groups. T-test analyses were conducted and revealed significant differences for parent-reported involvement in adolescents' diabetes care, $t(81) = 3.01$; $p < .01$, with parents of Caucasian youth reporting more adolescent autonomy for their diabetes care than for non-Caucasian adolescents. There were also differences between these groups for two of the subtests from the D-KEFS Trail Making Test. Specifically, Number Sequencing, $t(81) = 2.24$; $p < .05$, and Motor Speed, $t(81) = 2.00$; $p < .05$, abilities significantly differed, such that Caucasian adolescents demonstrated more developed executive abilities as assessed by those measures compared to adolescents of an ethnic minority background.

Parent-reported diabetes-related conflict experienced with adolescents significantly differed based on family income, $F(2,78) = 4.27$, $p < .05$. Post hoc analyses indicated that families who earned less than $60,000/year reported significantly more conflict than families earning more than $121,000/year. Adolescents' metabolic control, as measured by their most recent HbA_{1c} values, also differed significantly among families based on family income. Specifically, post hoc analyses revealed differences among those families in the highest earnings bracket (>$121,000/year; mean HbA_{1c} = 8.02%; SD = 1.04) and those families with the lowest annual incomes (<$60,000/year; mean HbA_{1c} = 9.12%; SD = 1.85). More affluent families had adolescents who maintained significantly better metabolic control compared to families with the lowest income in this study.

Due to the discrepancy in diagnostic group sizes, Mann-Whitney U tests were performed to compare the ranks for the $n = 8$ adolescents with a diagnosis of ADHD and the $n = 76$ adolescents without a diagnosis of ADHD. Parent and youth report of adolescents' executive functioning abilities differed significantly based on adolescents' diagnostic history of ADHD. According to parent-reported Global Executive Composite scores on the BRIEF, parents reported significantly poorer executive functioning skills for youth with a preexisting diagnosis of ADHD (mean rank = 70.63) as compared to youth without such a diagnosis (mean rank = 39.54), $Z = -3.43$; $p < .01$. Likewise, this same difference was found when examining adolescents' reports of their own executive functioning on the BRIEF-SR, such that adolescents with a diagnosis of ADHD (mean rank = 60.00) endorsed poorer executive functioning compared to adolescents without a diagnosis of ADHD (mean rank = 40.66), $Z = -2.14$; $p < .05$.

Examination of neuropsychological tests of executive functioning demonstrated one significant difference in performance based on diagnostic history of ADHD. Performance on the Wisconsin Card Sorting Task (Total Administration), $Z = -2.66$; $p < .01$, revealed poorer executive functioning for adolescents who had a diagnosis of ADHD (mean rank = 64.19) compared to those adolescent without such a diagnosis (mean rank = 40.22).

Diabetes-related demographic covariates.

Results revealed significant differences in several areas of adolescents' functioning based on their method of insulin administration. Adolescents who administered their insulin with syringes or pens endorsed significantly more T1DM-related conflict with their parents than those who were on an insulin pump, $t(79) = 2.46$; $p < .01$. Additionally, adolescents who were on an insulin pump were in better metabolic control, as evidenced by lower HbA_{1c} values, $t(79) = 2.39$; $p < .01$, and also tested and logged their blood glucose levels more frequently, $t(57) = -3.77$; $p < .05$, than adolescents who used syringes or pens to dose and administer their insulin.

Analyses also revealed significant differences in adolescents' executive functioning based on the method of insulin administration. On a parent report measure of adolescents' executive functioning (BRIEF), parents indicated that adolescents who administer their insulin with syringes or pens have greater problems with behavioral inhibition (Inhibit subscale) than those who are on an insulin pump, $t(79) = 2.46$; $p < .05$. Adolescents who use syringes or pens to administer their insulin reported more problems with behavioral inhibition, $t(79) = 2.03$; $p < .05$, and endorsed greater difficulty completing a task (BRIEF-SR Task Completion subscale), $t(79) = 2.07$; $p < .05$, as compared to adolescents who were on an insulin pump. Performance on a neuropsychological measure assessing several aspects of goal-directed behavior such as spatial planning, self-guided action, and maintenance of an instructional set (i.e., D-KEFS Tower Task Total Achievement Score) also differed based on adolescents' method of insulin administration. Adolescents who used syringes or pens displayed significantly lower scores on this measure as compared to youth who were on a pump, $t(79) = -2.12$; $p < .05$. The aforementioned findings examining the differences among those youth who receive their insulin via syringe/pen vs. a pump are not altogether surprising given the philosophy of the CHW diabetes clinic regarding which families are eligible for a pump. In this clinic, which tends to be somewhat conservative with pump distribution, families who are interested in receiving a pump have to demonstrate a generally high level of successful management over a period of time using syringes/pens before a pump will be prescribed.

Correlations among self-report and neuropsychological measures of executive functioning

In order to gain a comprehensive assessment of adolescents' executive functioning abilities, the present study utilized self and parent report measures in addition to performance-based neuropsychological measures of the construct. We examined correlations among index scores from the parent-reported BRIEF, adolescent-reported BRIEF-SR, and neuropsychological measures of executive functioning to determine the extent to which these measures were assessing similar aspects of executive functioning. These correlations are presented in Tables 6 and 7. In general, there were very few statistically significant correlations between these two methods of executive functioning assessment.

Examination of Participants in the Early Onset Diagnosis Group

Based on previous research findings that suggest poorer neurocognitive functioning among youth who were diagnosed with T1DM prior to age seven (early onset diagnosis group) compared to youth who were diagnosed later in life, t-test analyses were conducted to examine differences in participants' performance on measures of neuropsychological functioning, self- and parent-report measures of executive functioning, and measures of illness management by age of T1DM onset. Of the total sample, 28 adolescents (33.3%) were in the early onset diagnosis group. Analyses revealed no statistically significant differences based on age of diagnosis for the BRIEF or BRIEF-SR scores. The only significant difference on self-report measures of illness management was on the adolescent-reported DFRQ which measures responsibility sharing for diabetes care. Adolescents in the early onset group reported having more responsibility for the independent management of their T1DM care compared to adolescents who were diagnosed later in life, $t(82) = -2.28$; $p < .05$. There were no

Table 6. Correlations Among BRIEF and BRIEF-SR Index Scores and D-KEFS Subscales

Variable	BRIEF BRI	BRIEF MCI	BRIEF GEC	BRIEF-SR BRI	BRIEF-SR MCI	BRIEF-SR GEC
D-KEFS Trail Making						
Visual Scanning	-.13	-.20	-.21	-.06	-.10	-.09
Number Sequencing	-.05	-.15	-.15	-.07	-.20	-.13
Letter Sequencing	.06	.01	.02	-.20	-.25*	-.25*
Number-Letter Sequencing	-.12	-.07	-.13	-.15	-.10	-.13
Motor Speed	-.12	.06	-.01	-.27*	-.08	-.17
D-KEFS Verbal Fluency						
Letter Fluency Total	.09	.05	.07	.06	.02	.07
Category Fluency Total	-.01	.04	.04	-.10	-.10	-.11
Category Switching Total	.03	.01	.03	-.01	-.08	-.03
Percent Set Loss	-.06	.03	.01	-.09	.07	.01
Percent Repetition	.06	.20	.13	.21	.14	.17
D-KEFS Tower Task						
Total Achievement	-.12	-.05	-.08	-.11	.02	-.03
Move accuracy	-.06	.01	-.03	-.14	-.04	-.06

* $p < .05$.

Table 7. Correlations Among BRIEF and BRIEF-SR Index Scores and Neuropsychological Measures of Executive Functioning, Intelligence, and Memory

Variable	BRIEF BRI	BRIEF MCI	BRIEF GEC	BRIEF-SR BRI	BRIEF-SR MCI	BRIEF-SR GEC
Wisconsin Card Sorting Task						
Total Items Administered (raw)	.13	.18	.17	.02	.09	.04
Categories Completed (raw)	-.21	-.21	-.21	-.01	-.06	-.02
Failure to Maintain Set (raw)	-.04	-.03	-.06	-.04	-.01	-.03
Perseverative Errors	-.12	-.16	-.15	-.01	-.09	-.03
Non-Perseverative Errors	-.16	-.21	-.22*	-.06	-.08	-.06
Rey-Osterrieth Complex Figure						
Copy Score	-.02	-.09	-.01	-.23*	-.14	-.18
Delay Score	-.15	-.11	-.11	-.16	-.13	-.15
WASI						
Full Scale IQ (FSIQ)	-.02	-.06	-.02	-.05	-.04	-.03

* $p < .05$.

significant differences between these two groups for any of the performance-based measures of neuropsychological functioning.

Consistent with previous research, which generally has found an association between treatment adherence and metabolic control, parents', $r = -.23$, $p < .05$, and youth's, $r = -.37$, $p < .01$, reports of adolescent's treatment adherence were significantly related to most recent HbA_{1c} values. Data collected from participants' blood glucose records (i.e., average number of blood glucose checks per day), which provided a proxy measure of treatment adherence, was also significantly related to adolescents' metabolic control, $r = -.25$, $p < .05$. There was a moderate level of agreement between parent and adolescent reports of adolescent treatment adherence as measured by the SCI-R, $r = .57$, $p < .01$.

Hypotheses Ia and Ib: Associations Among Adolescents' Executive Functioning, Treatment Adherence, and Metabolic Control

To examine the first set of hypotheses, bivariate correlations were examined among adolescents' executive functioning variables, treatment adherence (as measured by parent and adolescent report and by average daily blood glucose checks), and metabolic control (as measured by participants' most recent HbA_{1c} values).

Associations among parent- and adolescent-reported BRIEF scores, adolescent treatment adherence, and metabolic control.

Bivariate associations among executive functioning variables, as measured by parent-reported BRIEF, and adolescent' treatment adherence and metabolic control are presented in Table 8a and 8b. Higher scores on the BRIEF represent greater levels of executive dysfunction. Several subscales on the parent-reported BRIEF were

Table 8a. Correlations Among Parent-Reported BRIEF Subscales (T-Scores), Measures of Adolescent Treatment Adherence, and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Blood Glucose Checks	HbA_{1c}
BRIEF (Parent Report)				
Inhibit	-.39**	-.11	-.20	.18
Shift	-.10	. .08	.02	-.03
Emotional Control	-.18	-.08	-.09	.09
Initiate	-.39**	-.18	-.09	.18
Working Memory	-.41**	-.16	-.24	.16
Planning/Organization	-.36**	-.15	-.23	.29**
Organization	-.36**	-.24*	-.24	.11
Monitoring	-.34**	.01	-.22	.05
Behavioral Regulation Index	-.26*	-.06	-.11	.11
Metacognition Index	-.39**	-.17	-.23	.20
Global Executive Composite	-.41**	-.13	-.20	.16

* $p < .05$. ** $p < .01$

Table 8b. Correlations Among Parent-Reported BRIEF Subscales (Raw Data), Measures of Adolescent Treatment Adherence, and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Blood Glucose Checks	HbA_{1c}
BRIEF (Parent Report)				
Inhibit	-.31**	-.01	-.28*	.09
Shift	-.06	.15	-.14	-.10
Emotional Control	-.13	.01	-.18	.03
Initiate	-.35**	-.07	-.21	.09
Working Memory	-.34**	-.02	-.28*	.11
Planning/Organization	-.31**	-.01	-.30*	.20
Organization	-.30**	-.10	-.28*	.05
Monitoring	-.30**	.10	-.30*	.02
Behavioral Regulation Index	-.20	.01	-.16	.07
Metacognition Index	-.41**	-.16	-.18	.22*
Global Executive Composite	-.35**	-.12	-.09	.17

* $p < .05$. ** $p < .01$

significantly associated with parents' reports of adolescents' treatment adherence (SCI-R). Specifically, the Global Executive Composite, which is an aggregate score reflecting adolescent's overall executive abilities, was significantly inversely associated with adolescents' treatment adherence, $r = -.41$, $p < .01$. There was a significant association between the BRIEF Organization subscale score and adolescents' reports of their own treatment adherence, $r = -.24$, $p < .05$. There were no significant correlations among parent-reported BRIEF T-scores and adolescents' average number of blood glucose checks.

Bivariate associations among executive functioning variables, as measured by the adolescent-reported BRIEF-SR, and adolescents' treatment adherence and metabolic control are presented in Tables 9a and 9b. There were several significant associations between subscales on the BRIEF-SR and adolescents' report of their own treatment adherence (SCI-R) and an objective measure of adherence (i.e., average number of blood glucose checks). The Global Executive Composite score was significantly related with adolescent-reported treatment adherence, $r = -.40$, $p < .01$, and with the average number of blood glucose checks, $r = -.30$, $p < .05$. Examination of data across reporters revealed several significant associations among BRIEF-SR subscales and parents' reports of adolescents' executive functioning. Specifically, the Planning/Organization scale, $r = -.26$, $p < .05$, Organization scale, $r = -.23$, $p < .05$, Task Completion scale, $r = -.24$, $p < .05$, and the Metacognition Index, $r = -.23$, $p < .05$, scores were significantly related to parent reported SCI-R scores. These results suggest that adolescents who displayed behaviors consistent with better developed executive functions tended to be more adherent to their diabetes treatment regimen.

Table 9a. Correlations Among Adolescent-Reported BRIEF-SR Subscales (T-scores), Measures of Adolescent Treatment Adherence, and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Average BG Checks	HbA_{1c}
BRIEF-SR (Adolescent Report)				
Inhibit	-.11	-.33**	-.27*	.21
Shift	-.05	-.28*	-.30*	.12
Emotional Control	-.02	-.29**	-.23	.06
Monitoring	-.12	-.21	-.34**	.18
Working Memory	-.11	-.28*	-.28*	.05
Planning/Organization	-.26*	-.41**	-.28*	.24*
Organization	-.23*	-.29**	-.04	.16
Task Completion	-.24*	-.29**	-.19	.33**
Behavioral Regulation Index	-.05	-.32**	-.30*	.14
Metacognition Index	-.23*	-.36**	-.27*	.19
Global Executive Composite	-.19	-.40**	-.30*	.18

* $p < .05$. ** $p < .01$

Table 9b. Correlations Among Adolescent-Reported BRIEF-SR Subscales (Raw Data), Measures of Adolescent Treatment Adherence, and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Average BG Checks	HbA_{1c}
BRIEF-SR (Adolescent Report)				
Inhibit	-.13	-.33**	-.24	.22*
Shift	-.06	-.24*	-.27*	.16
Emotional Control	-.01	-.31**	-.21	.11
Monitoring	-.13	-.23*	-.33**	.22*
Working Memory	-.11	-.29**	-.26*	.10
Planning/Organization	-.27*	-.41**	-.24	.28*
Organization	-.24*	-.30**	-.01	.22*
Task Completion	-.26*	-.32**	-.20	.39**
Behavioral Regulation Index	-.07	-.35**	-.31*	.16
Metacognition Index	-.25*	-.37**	-.23	.22*
Global Executive Composite	-.20	-.39**	-.29*	.20

* $p < .05$. ** $p < .01$

There were not many significant associations among BRIEF subscale T-scores and adolescents' HbA_{1c} values; however, the Planning/Organization subscale score was significantly associated with adolescents' HbA_{1c} values, $r = .29$, $p < .01$, such that adolescents who had more developed planning and organizational abilities displayed better metabolic control. Similarly, there were not many significant relationships between BRIEF-SR scales and adolescent's HbA_{1c} values, although the Planning/Organization, $r = .24$, $p < .05$, and Task Completion, $r = .33$, $p < .01$, subscales were significantly related to HbA_{1c} values, suggesting that adolescents who had more developed executive skills related to planning, organization, and completion of tasks displayed better metabolic control.

Associations among performance-based measures of adolescents' neurocognitive functioning, treatment adherence, and metabolic control.

The current analyses also explored bivariate associations among performance-based neuropsychological measures of adolescents' executive functioning, treatment adherence, and metabolic control. These correlations are presented in Tables 10a, 10b, and 11. Analyses revealed few statistically significant relationships among these constructs. Parent report of adolescents' treatment adherence was significantly related to the percent of repetition errors on the D-KEFS Verbal Fluency task, $r = -.22$, $p < .05$, and Non-Perseverative Errors on the Wisconsin Card Sorting Task (WCST), $r = .27$, $p < .05$. The average number of daily blood glucose checks was significantly correlated with the Number Sequencing task from the D-KEFS, $r = -.25$, $p < .05$, which suggests that adolescents who were more efficient in their sequencing abilities tended to have fewer

Table 10a. Correlations Among D-KEFS Subscales (Scaled Scores) with Measures of Adolescent Treatment Adherence, and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Average BG Checks	HbA_{1c}
D-KEFS Trail Making Task (scaled scores)				
Visual Scanning	.05	-.13	-.18	-.05
Number Sequencing	.05	-.07	-.25*	.01
Letter Sequencing	-.11	-.16	-.15	-.11
Number-Letter Sequencing	.06	-.08	-.07	.03
Motor Speed	-.03	-.03	.04	-.05
D-KEFS Verbal Fluency Task (scaled scores)				
Letter Fluency Total Score	-.10	-.06	-.06	-.06
Category Fluency Total Score	-.17	-.12	-.06	.01
Category Switching Total Score	.05	.14	.02	-.02
Percent Set Loss Errors	-.10	.01	-.11	.05
Percent Repetition Errors	-.22*	-.21	-.10	.03
D-KEFS Tower Task (scaled scores)				
Total Achievement	-.05	-.11	.06	.01
Move accuracy	-.17	-.13	-.01	.08

* $p < .05$.

Table 10b. Correlations Among D-KEFS Subscales (Raw Data) with Measures of Adolescent Treatment Adherence and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Average BG Checks	HbA_{1c}
D-KEFS Trail Making Task (scaled scores)				
Visual Scanning	.02	.18	.21	-.05
Number Sequencing	-.01	.11	.36**	-.03
Letter Sequencing	.11	.18	.25	.09
Number-Letter Sequencing	-.03	.17	.21	-.09
Motor Speed	.05	.04	.04	.01
D-KEFS Verbal Fluency Task (scaled scores)				
Letter Fluency Total Score	-.20	-.16	-.15	.04
Category Fluency Total Score	-.20	-.16	-.15	.04
Category Switching Total Score	.01	.09	-.04	.10
Percent Set Loss Errors	.09	.01	.13	-.05
Percent Repetition Errors	.15	.10	.01	-.04
D-KEFS Tower Task (scaled scores)				
Total Achievement	-.07	-.16	.01	.01
Move accuracy	.17	.12	.01	-.07

** $p < .01$.

Table 11. Correlations Among Neuropsychological Measures of Executive Functioning, Intelligence, and Memory with Measures of Adolescent Treatment Adherence and Metabolic Control

Variable	SCI-R Parent	SCI-R Youth	Average BG Checks	HbA_{1c}
Wisconsin Card Sorting Task				
Total Items Administered (raw score)	-.18	-.05	-.13	.15
Categories Completed (raw score)	.14	.01	.20	-.07
Failure to Maintain Set (raw score)	-.05	-.08	-.11	.11
Perseverative Errors (T-score)	.09	.01	.09	-.15
Non-Perseverative Errors (T-score)	.27*	.08	.13	-.12
Rey-Osterrieth Complex Figure				
Copy score (T-score)	-.13	-.17	-.12	.04
Delay score (T-score)	-.01	-.12	-.11	-.05
Wechsler Abbreviated Scale of Intelligence				
Full Scale IQ (FSIQ; standard score)	.05	-.02	.08	-.23*

* $p < .05$.

blood daily blood glucose checks. There were no meaningful associations among any of the neuropsychological measures of executive functioning and adolescents' reports of treatment adherence (SCI-R) or HbA_{1c} values, which is a finding that is consistent with what was found in the DCCT (DCCT, 1994).

In addition to exploring the relationships among neuropsychological measures of executive functioning with treatment adherence and metabolic control, we also examined these relationships with brief measures of adolescents' memory (i.e., Rey-Osterrieth Compex Figure) and intelligence (i.e., WASI; see Table 11). The only statistically significant relationship that emerged among these measures of neuropsychological functioning and illness management was between adolescents' Full Scale IQ (FSIQ) and HbA_{1c} values, $r = -.23$, $p < .05$, such that adolescents with more developed intellectual abilities displayed better metabolic control.

Hypotheses IIa and IIb: Relative Contributions of Illness Management, Family Functioning, and Executive Functioning Variables in the Prediction of Adolescents' Treatment Adherence

To test the second set of hypotheses, a series of hierarchical multiple regressions were conducted. The first hierarchical multiple regression examined the contributions of parental involvement and monitoring, diabetes-related conflict, and parent reports of adolescent's executive functioning in the prediction of parent-reported adolescent treatment adherence. Results from the regression are presented in Table 12 and represent the contributions at each step of the regression and the final regression model. The demographic variables that were significantly related to the predictor variables (i.e., adolescent age, family income, adolescent sex, adolescent diagnosis of ADHD) were

Table 12. Multiple Regression Effects for Parent-Reported Family Functioning Variables and Executive Functioning Predicting Parent-Reported Adolescent Treatment Adherence

Step		Unstandardized β	Standard Error	Standardized β	R^2	ΔR^2
1.	Adolescent age	-1.87	.84	-.25*		
	Family income	1.71	.95	.20		
	Adolescent sex	4.08	2.96	.15		
	ADHD diagnostic status	-1.98	5.06	-.04	.11	.11
2.	Parent involvement	.85	.35	.32*		
	Parental monitoring	.32	.10	.33**	.25	.14**
3.	T1DM-related conflict	-.67	.27	-.28*	.31	.06*
Final Model:						
4.	Adolescent age	-1.71	.95	-.23		
	Family income	.59	.90	.07		
	Adolescent's sex	1.22	2.64	.05		
	ADHD diagnostic status	-8.14	4.77	-.18		
	Parent involvement	.45	.35	.17		
	Parental monitoring	.28	.10	.30**		
	T1DM-related conflict	-.48	.27	-.20		
	Global Executive					
	Composite (BRIEF)	-.42	.15	-.31**	.37	.06**

* *p*< .05. ***p*< .01

entered into the regression first, measures of parent-reported involvement in and monitoring of T1DM care were entered second, parents' reports of the diabetes-related conflict was entered third, and parents' report of adolescents' executive functioning (i.e. Global Executive Composite score from the BRIEF) was entered fourth. Although it was initially proposed that the regression models would include adolescents' intellectual functioning and memory to examine the relative contributions of these neurocognitive variables in addition to executive functioning, these variables were not included in analyses due to the lack of significant relationships with the variables of interest at a bivariate level.

The results of the regression indicated that the overall model was significant, $F(8,80) = 5.38$, $p < .01$, and predicted about 37% of the variance in parent-reported adolescent treatment adherence. The demographic variables, R^2 change = .11, $F(4,80) = 2.23$, $p = .07$, did not account for a significant percentage of variance in the prediction of adolescents' treatment adherence. In the second step, parental involvement and monitoring contributed a significant amount of unique variance in predicting treatment adherence, R^2 change = .14, $F(6,80) = 4.06$, $p < .01$, as did parent-adolescent conflict, which was entered in the third step of the regression, R^2 change = .06, $F(7,80) = 4.71$, $p < .01$. Parent-reported adolescent executive functioning was entered in the final step of the regression. This variable added a significant amount of unique variance in predicting adolescent treatment adherence after taking into account the related demographic variables, illness management, and family functioning variables, R^2 change = .06, $F(8,80) = 5.38$, $p < .01$. In the final model, parental monitoring of diabetes management and adolescent's executive functioning were the only significant predictors of adolescent treatment adherence.

A second hierarchical multiple regression was conducted to examine the contributions of parental monitoring, diabetes-related conflict, and adolescents' reports of their executive functioning in the prediction of adolescent-reported treatment adherence. Results from the regression are presented in Table 13 and represent the contributions at each step of the regression and the final regression model. The demographic variables that were significantly related to the predictor variables (i.e., adolescent age, parent ethnicity, adolescent ADHD diagnostic status, method of insulin administration) were entered into the regression, a measure of adolescent-reported parental monitoring of T1DM care was entered second, adolescent report of diabetes-related conflict was entered third, and adolescents' report of adolescents' executive functioning (i.e. Global Executive Composite score from the BRIEF-SR) was entered fourth.

The results of the regression indicated that the overall regression model was significant, $F(7,79) = 6.02$, $p < .01$, and predicted about 37% of the variance in adolescents' treatment adherence. The demographic variables, R^2 change = .13, $F(4,79) = 2.84$, $p < .05$, predicted a significant percentage of variance in treatment adherence. In the second step, parental monitoring of adolescents' diabetes management contributed a significant amount of unique variance in predicting treatment adherence as well, R^2 change = .06, $F(5,79) = 3.52$, $p < .05$. Similar to the results from the previous regression examining parent-reported measures, adolescent-reported diabetes-related conflict also contributed a unique amount of variance in predicting treatment adherence, R^2 change = .13, $F(6,79) = 5.84$, $p < .01$. In the final step, adolescent-reported executive functioning

Table 13. Multiple Regression Effects for Adolescent-Reported Family Functioning Variables and Executive Functioning Predicting Adolescent-Reported Treatment Adherence

Step		Unstandardized β	Standard Error	Standardized β	R^2	ΔR^2
1.	Adolescent age	-2.27	.78	-.33**		
	Parent's ethnicity	-2.64	1.86	-.16		
	ADHD diagnostic status	-4.57	4.65	-.11		
	Insulin administration type	1.17	3.03	.04	.13	.13*
2.	Parental monitoring	.28	.12	.30*	.19	.06*
3.	T1DM-related conflict	-40.97	10.84	-.38**	.32	.13**
Final Model:						
4.	Adolescent age	-1.68	.84	-.24		
	Parent's ethnicity	-.95	1.66	-.06		
	ADHD diagnostic status	-7.92	4.23	-.19		
	Insulin administration type	-1.23	2.72	-.05		
	Parental monitoring	.22	.11	.24*		
	T1DM-related conflict	-34.45	10.94	-.32**		
	Global Executive					
	Composite (BRIEF-SR)	-.28	.12	-.24*	.37	.05*

* *p*< .05. ***p*< .01

also contributed a unique amount of variance in predicting adolescents' treatment adherence after taking into account the related demographic variables, illness management, and family functioning variables, R^2 change = .05, $F(7,79) = 6.02$, $p < .05$. Examination of the final model revealed that parental monitoring of diabetes care, diabetes-related conflict, and adolescent executive functioning were the only significant predictors of treatment adherence.

A third hierarchical regression was conducted to examine the prediction of adolescents' metabolic control, as measured by their most recent HbA_{1c} values. Results from the regression are presented in Table 14 and represent the contributions at each step of the regression and the final regression model. In this regression model, the demographic variables that were significantly related to the predictor variables (i.e., adolescent age, length of T1DM diagnosis, family income) were entered first and accounted for about 15% of the variance in predicting adolescents' HbA_{1c} values, $R^2 = .15$, $F(3,77) = 4.58$, $p < .01$. A measure of adolescents' intellectual functioning (FSIQ) was included in the second step of the model due to its significant relationship with adolescents' metabolic control at the bivariate level. After taking into account the related demographic variables, adolescent IQ did not account for a significant percentage of unique variance in predicting HbA_{1c} values. Similarly, adolescent-reported parental monitoring of diabetes care also was not a significant predictor of metabolic control in the third step. In the fourth step of the model, parent-adolescent diabetes-related conflict did account for a significant percentage of unique variance in predicting HbA_{1c} values [R^2 change = .08; $p < .01$]. The Planning and Organization subscale score from the BRIEF-SR was added in the final step of the regression because it was the only subscale from the

Table 14. Multiple Regression Effects for Intelligence, Adolescent-Reported Parental Monitoring, Parent-Reported Diabetes Related Conflict, and Adolescent-Reported Executive Functioning Predicting Adolescents' HbA_{1c} values

Step	Unstandardized β	Standard Error	Standardized β	R^2	ΔR^2
1. Adolescent age	.89	.01	.09		
Length of diagnosis	.01	.00	.18		
Family income	-.01	.01	-.28*	.15	.15**
2. Full Scale IQ (FSIQ)	-.01	.00	-.16	.18	.03
3. Parental monitoring	.00	.00	-.13	.19	.01
4. T1DM-related conflict	.26	.09	.30**	.27	.08**
Final Model					
5. Adolescent age	.00	.01	.02		
Length of diagnosis	.00	.00	.22*		
Family income	-.00	.01	-.14		
Full Scale IQ (FSIQ)	.00	.00	-.14		
Parental monitoring	.00	.00	-.11		
T1DM-related conflict	.22	.10	.25*		
Planning and organization					
(BRIEF-SR)	.15	.10	.17	.29	.02

* $p < .05$. ** $p < .01$.

BRIEF-SR that was significantly associated with metabolic control at the bivariate level; this measure of executive functioning did not contribute a significant amount of unique variance to the model. The overall model was significant and accounted for about 29% of the variance in predicting adolescent's HbA_{1c} values, $F(7,73) = 4.23$, $p < .01$. Examination of the final model revealed that length of T1DM diagnosis and diabetes-related conflict were the only significant predictors of metabolic control.

Hypotheses IIIa, IIIb, IIIc, IIId, IIIe, and IIIf: Moderation of Executive Functioning and Treatment Adherence by Parental Involvement and Monitoring

Moderation analyses were used to determine if variables assessing parental contributions to adolescents' diabetes care (e.g. parental monitoring, parental involvement) served as moderators to the relationships between adolescents' executive functioning abilities and treatment adherence. Several moderations were examined to assess parent- and adolescent-reported measures of the aforementioned constructs. Although initially proposed, we did not examine moderation models involving the prediction of adolescents' HbA_{1c} values due to a lack of significant associations among the constructs of interest at the bivariate level.

All of the moderation analyses were conducted using hierarchical multiple regressions. First, the independent variables and the moderators were "centered" to reduce the effects of multicollinearity (Aiken & West, 1991). Centering these variables involved subtracting the sample means from each of the scores. The related demographic variables were entered into the first step of the regressions followed by the main effects of the moderators and predictors, and the interaction of the moderators and predictors were entered into the final step of the regressions. Baron and Kenney (1986) guidelines were used, which state that statistical moderation is met if there is a significant interaction between the moderator and the independent variable, after the effects of the moderator and independent variable are controlled for.

Moderation of parent-reported adolescent executive functioning and treatment adherence by parent-reported involvement and monitoring of diabetes care.

The first set of moderation analyses examined the prediction of parent-reported adolescent treatment adherence. Results depicting the final models of these regressions are presented in Table 15. The regression equation testing the hypothesis that parental involvement would moderate the relationship between adolescent's executive functioning and treatment adherence was found to be statistically significant and explained about 23% of the variance in predicting adolescent's treatment adherence, $F(4,83) = 5.96$, $p < .001$.

In the first step, adolescent sex was entered (male =1; female = 2), as it was significantly related to parent reports of their involvement in diabetes care. Parent reports of adolescent executive functioning (BRIEF Global Executive Composite; BRIEF GEC) was entered second and contributed a significant amount of unique variance, R^2 change = .16, $F(2,83) = 8.03$, $p < .01$, in predicting adolescent treatment adherence; adolescent executive functioning was a significant predictor of adherence in the final model as well, $\beta = -.41$, $t(83) = -4.03$, $p < .001$. In the third step, parent-reported parental involvement in diabetes care (DFRQ Parent) was entered, but this variable did not predict a significant amount of unique variance in adolescents' treatment adherence, R^2 change = .01, $F(3,83) = 5.31$, $p > .05$. In the final step of the regression analysis, an interaction term between

Table 15. Summary of Regression Analyses Testing Moderation Models Predicting Parent-Reported Adolescent Treatment Adherence

Moderation	Predictor Variable	*F*	R^2	*p*	β
Model #1	Adolescent sex	5.96	.23	< .001	-.01
	BRIEF GEC				-.41**
	DFRQ parent				.04
	BRIEF x DFRQ				-.26*
Model #2	Adolescent age	6.72	.25	< .001	-.09
	BRIEF GEC				-.36**
	PMDC parent				.26*
	BRIEF x PMDC				-.03
Model #3	Adolescent age	5.28	.21	< .01	-.11
	BRIEF GEC				-.40**
	Parental contributions (Parent-report)				.09
	BRIEF x Parental contributions				.12

* $p < .05$. ** $p < .01$.

adolescents' executive functioning and parental involvement was created, which accounted for a significant proportion of the variance in treatment adherence, R^2 change = .07, p <.05, β = -.26, t(83) = -2.60, p < .05. These results suggest that parental involvement does serve as a significant moderator to the relationship of adolescents' executive functioning and treatment adherence. Specifically, adolescents with better executive functioning abilities were more adherent to their treatment regimen, especially when parents were less involved in adolescents' diabetes management. This interaction model is displayed in Figure 2.

A second moderation model was conducted to determine whether parental monitoring served as a moderator to the relationship between adolescent executive functioning and treatment adherence. Adolescent age was entered in the first step, and it contributed a significant amount of variance in predicting treatment adherence, R^2 = .05, F(1,83) = 4.10, p < .05. The main effects of parent-reported adolescent executive functioning and parental monitoring were entered in the second and third steps, respectively, and each was found to contribute a significant amount of variance in predicting adherence. Adolescents' executive functioning, β = -.36, t(83) = -3.67, p < .001, and parental monitoring, β = .26, t(83) = 2.54, p < .05, variables were both found to be significant predictors in the final model. In the final step of the regression analysis, an interaction term between adolescents' executive functioning and parental monitoring was created, which did not account for a significant proportion of the variance in treatment adherence, R^2 change = .01, p > .05, β = -.03, t(83) = -.31, p > .05.

A third moderation model examining the prediction of parent-reported adolescent treatment adherence was conducted examining parental contributions to adolescents'

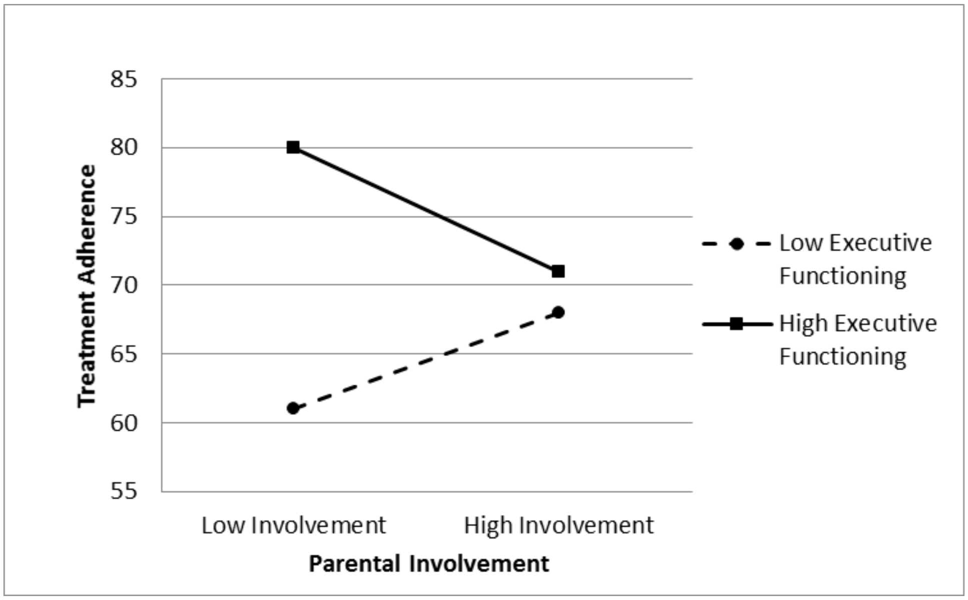

Figure 2. Parent-Reported Involvement in Adolescents' Diabetes Care Moderates the Relationship Between Adolescents' Executive Functioning and Treatment Adherence

diabetes care. An aggregate variable was created, combining parents' reports of their involvement and monitoring behaviors in order to capture their overall contributions in assisting in adolescents' diabetes management. In this model, adolescent age was entered in the first step, as it was a significant demographic covariate. This demographic variable contributed a significant amount of variance in predicting adolescent treatment adherence, as did parents' reports of adolescents' executive functioning, which was entered in the second step, R^2 change = .14, $F(2,83) = 9.56$, $p < .001$. The aggregate score assessing parental contributions to diabetes care (Parental Contributions) was entered in the third step of the regression and did not contribute a significant amount of variance in predicting treatment adherence. Similarly, when an interaction term between adolescents' executive functioning and parental contributions was entered in the fourth step of the regression model, this variable was not a significant predictor, R^2 change = .01, $p > .05$, $\beta = .12$, $t(83) = 1.19$, $p > .05$.

Moderation of adolescent-reported executive functioning and treatment adherence by adolescent-reported parental involvement and monitoring of diabetes care.

The second set of moderation analyses examined the prediction of adolescent-reported treatment adherence. Results depicting the final models of these regressions are presented in Table 16. The first regression equation tested the hypothesis that adolescent-reported parental involvement would moderate the relationship between adolescents' executive functioning and treatment adherence. The overall model was found to be statistically significant and explained about 26% of the variance in predicting adolescent's treatment adherence, $F(4,83) = 6.96$, $p < .001$. In the first step, adolescent

Table 16. Summary of Regression Analyses Testing Moderation Models Predicting Adolescent-Reported Treatment Adherence

Moderation	Predictor Variable	*F*	R^2	*p*	β
Model #1	Adolescent age	6.96	.26	< .001	-.47**
	BRIEF-SR GEC				-.33**
	DFRQ adolescent				.25
	BRIEF-SR x DFRQ				-.19[a]
Model #2	Adolescent age	6.66	.25	< .001	-.16
	BRIEF-SR_GEC				-.28**
	PMDC adolescent				.29*
	BRIEF-SR x PMDC				-.01
Model #3	Adolescent age	1.40	.07	> .05	.08
	BRIEF-SR_GEC				.19
	Parental contributions (Youth-report)				-.06
	BRIEF-SR x Parental contributions				.09

[a] $p = .07$. * $p < .05$. ** $p < .01$.

age was entered, as it was significantly related to adolescent report of treatment adherence. Adolescent reports of executive functioning (BRIEF-SR Global Executive Composite; BRIEF-SR GEC) was entered second and contributed a significant amount of unique variance, R^2 change = .10, $F(2,83) = 9.83$, $p < .01$, in predicting adolescents' treatment adherence; adolescents' executive functioning was a significant predictor of adherence in the final model as well, $\beta = -.33$, $t(83) = -3.13$, $p < .01$. In the third step, adolescent-reported parental involvement in diabetes care (DFRQ Adolescent) was entered; this variable did not predict a significant amount of unique variance in adolescents' treatment adherence, R^2 change = .03, $F(3,83) = 7.90$, $p = .07$. In the final step of the regression analysis, an interaction term between adolescents' executive functioning and parental involvement was created, and this variable approached statistical significance, R^2 change = .03, $p = .07$, $\beta = -.19$, $t(83) = -1.85$, $p = .07$. These results suggest that parental involvement may serve as a significant moderator to the relationship of adolescents' executive functioning and treatment adherence; although this relationship was only at a trend level. Specifically, adolescents with better executive functioning abilities were somewhat more adherent to their treatment regimen, especially when parents were less involved in adolescents' diabetes management. This interaction model is displayed in Figure 3.

A regression equation was tested to examine the hypothesis that adolescent-reported parental monitoring would moderate the relationship between adolescent-reported executive functioning and treatment adherence. Adolescent age was entered in the first step, and it contributed a significant amount of variance in predicting treatment adherence, $R^2 = .09$, $F(1,83) = 8.42$, $p < .01$. The main effect of adolescent-reported

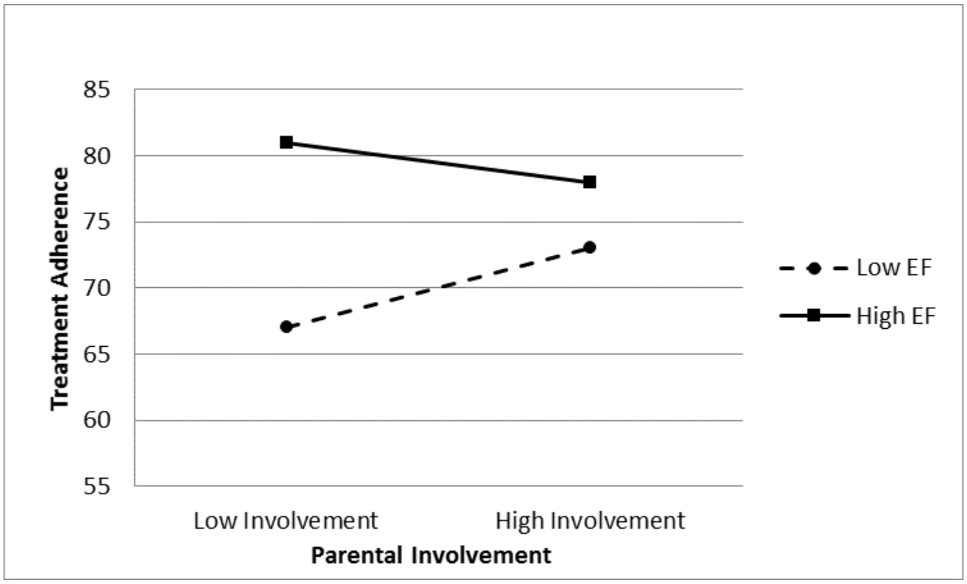

Figure 3. Adolescent-Reported Involvement in Adolescents' Diabetes Care Moderates the Relationship Between Adolescents' Executive Functioning and Treatment Adherence

executive functioning was entered in the second step, and it too contributed a significant amount of unique variance in predicting adherence, R^2 change = .10, $F(2,83) = 9.83$, $p < .01$. In the third step of the regression, parental monitoring (PMDC Adolescent) was entered, and it was also a significant predictor of adolescents' treatment adherence, R^2 change = .06, $F(3,83) = 8.98$, $p < .05$. In the final step of the regression analysis, an interaction term between adolescents' executive functioning and parental monitoring was created, which did not account for a significant proportion of the variance in treatment adherence, R^2 change = .00, $p > .05$, $\beta = -.01$, $t(83) = -.14$, $p > .05$.

The final moderation model that was conducted examined the hypothesis that parental contributions to adolescents' diabetes care would moderate the relationship between adolescent-reported executive functioning and treatment adherence. The "parental contributions" variable was a composite variable created from combining the adolescent-reported parental monitoring and involvement scores. In the first step of the regression, adolescent age was entered, adolescent-reported executive functioning was entered second, parental contributions to adolescents' diabetes management was entered third, and an interaction term combining executing functioning and parental contributions was entered fourth. The overall regression model predicted 6% of variance in adolescent's treatment adherence and was not significant, $F(4,83) = 1.40$, $p = .24$. In the final model, none of the main effects or interaction variable were significant predictors of adherence.

Discussion

This study sought to further examine the relationships among adolescents' executive functioning abilities, parental involvement in diabetes care, and treatment adherence and metabolic control among adolescents with type 1 diabetes mellitus. In general, results supported our hypotheses, in that adolescents with better developed parent and self-reported executive functions tended to display better adherence to their T1DM treatment regimen. Additionally, parent and self-reports of adolescent executive functioning were shown to be significant predictors of adherence beyond the contributions of several demographic and family functioning variables. Examination of parents' contributions to adolescents' T1DM management revealed that parental involvement was a significant moderator of the relationship between adolescents' executive functioning and treatment adherence, such that parental involvement had a larger impact for adolescents who demonstrated poorer executive functions.

Relationship Between Adolescents' Executive Functioning and Illness Management

The first hypothesis explored the associations between adolescents' executive functioning and treatment adherence and metabolic control. Executive functioning was assessed with parent- and adolescent-report measures as well as with performance-based neuropsychological measures. Results exploring relationships between a parent-report measure of adolescents' executive functioning and treatment adherence were consistent with previous research, which demonstrated a significant relationship between parent-reported BRIEF scores and parent-report of adolescent treatment adherence.

Similar results were obtained when examining the relationship of adolescent-reported executive functioning (BRIEF-SR) scores and adolescents' reports of their own adherence. Additionally, adolescent reports of executive functioning were also significantly related to parent-reported (SCI-R) and objective (frequency of blood glucose checks) measures of adherence, such that better developed executive functioning was significantly associated with better adherence and more frequent blood glucose checks. To our knowledge, this study is the first to demonstrate the relationship between adolescent-reported executive functioning and treatment adherence, as previous studies examining this association have typically utilized parent-report measures of adolescent executive functioning (Bagner et al., 2007; McNally et al., 2010). Given the complexities of managing an often changing and multi-step T1DM treatment regimen, this study offers additional evidence that executive functions may play a significant role in aiding adolescents in their self-management. Despite the robust correlations that were observed between parent- and self-reported executive functions and adherence, there were few significant associations found among neuropsychological measures of executive functioning and either measure of adherence (i.e., questionnaire or blood glucose check frequency). The lack of significant associations with the performance-based, neuropsychological measures is addressed later in the discussion.

A secondary aim of the first hypothesis was to examine relationships among adolescents' executive functioning and metabolic control, as assessed by recent HbA_{1c} values. Results from the current study suggested that there were few significant associations among parent and adolescent reports of overall executive functioning and adolescents' HbA_{1c} values. However, parent and adolescent reports of adolescents' planning and organizational abilities and adolescent reports of task completion were significantly correlated with HbA_{1c}. The Planning/Organize subscales on the BRIEF and BRIEF-SR assess adolescents' abilities to manage current and future-oriented task demands by assessing their capacity to anticipate future events, develop a goal, and determine the most effective and efficient way to reach that goal (Gioia et al., 2000).

Similarly, the Task Completion subscale on the BRIEF-SR assesses adolescents' abilities to develop an organized plan and to complete a multi-step task appropriately and efficiently (Guy et al., 2004). These results suggest that of the multifaceted domains that are involved in executive functioning, adolescents' abilities related to holding a goal in mind, developing a plan to achieve that goal, while inhibiting task-irrelevant actions may be particularly important skills for adolescents to manage their illness demands to maintain acceptable levels of metabolic control. Successful diabetes management requires youth to adjust their insulin dosage based on the results of blood glucose monitoring, assessment of the number of carbohydrates consumed, and amount of activity they have taken part in or will plan to do in the near future. For adolescents who have poorly developed executive functions, these tasks may be more difficult to successfully coordinate and execute.

Examination of the performance-based measures of executive functioning assessed in the current study revealed no significant correlations with adolescents' metabolic control; however, assessment of a measure of intelligence found that youth with higher FSIQ scores tended to have better metabolic control. The measure of intelligence was included in multivariate analyses involving the prediction of adolescents' HbA_{1c} values, and it was found to not be a significant predictor of metabolic control once several demographic characteristics (e.g., adolescent age, length of diagnosis, family income) were taken into account.

Prediction of Adolescents' Illness Management

The second hypothesis examined the prediction of adolescents' treatment adherence and metabolic control. Specifically, analyses examined the contributions of demographic characteristics, parent-adolescent relationship and illness management variables, and adolescents' executive functioning abilities in predicting the outcome variables described above. Three hierarchical regressions (two predicting adherence and one predicting metabolic control) were conducted to examine parent and adolescent-reported adherence and metabolic control. In the two regression models assessing the contributions of parent- and adolescent-reported variables in the prediction of adolescents' treatment adherence, executive functioning contributed a significant amount of unique variance after taking into account related demographic covariates, parental involvement and monitoring, and parent-adolescent T1DM-related conflict. In total, both of these models assessing parent and adolescent report of the constructs of interest accounted for about 37% of variance in predicting adolescent treatment adherence. Research has repeatedly demonstrated the importance of several demographic characteristics (e.g., age, ethnicity, method of insulin administration), parental involvement and monitoring, and T1DM-related conflict as characteristics that are related to illness management among adolescents diagnosed with T1DM (Helgeson et al., 2008; Palmer et al., 2004; Miller-Johnson et al., 1994). The findings in the present study offer continued support for all of these factors as significant predictors of adherence but also suggests that adolescents' executive functioning abilities may play an additionally important role in aiding in successful T1DM management. In the final model of both regressions, parent- and adolescent-report of parental monitoring and executive functioning were the only variables that significantly predicted adherence. These results suggest that in addition to variables assessing family management, such as parental monitoring, which has consistently demonstrated a positive association with adolescents' treatment adherence, perhaps there are cognitive factors that are also important for adolescents to successfully manage their T1DM treatment regimen.

In a regression model assessing the prediction of adolescents' metabolic control using both adolescent- and parent-report variables, adolescents' reports of their own executive functioning abilities (BRIEF-SR Planning and Organization subscale) were not found to contribute a significant percentage of unique variance. The final model suggested that length of T1DM diagnosis and parent-adolescent conflict were the only significant predictors of adolescents' HbA_{1c} values. This finding is consistent with previous longitudinal research which has found that improving parent-adolescent conflict resulted in better illness management outcomes, especially among older adolescents (Ingerski, Anderson, Dolan, & Hood, 2010).

Examination of the regression models predicting adherence found that T1DM-related conflict was not a significant predictor; however, conflict did account for a unique amount of variance in a regression predicting metabolic control. It is possible that this difference in findings may be a result of the selection of BRIEF and BRIEF-SR subscales included in the regressions assessing our two outcome variables. In analyses assessing the prediction of adherence, global executive composite scores were utilized. In contrast, the Planning and Organization subscale was included in analyses predicting metabolic control, due to it being the only variable from the BRIEF and BRIEF-SR significantly related to HbA_{1c} values at a bivariate level. Preliminary analyses from this study revealed strong associations between global executive composite scores from the BRIEF and a measure of parenting stress (Stress Index for Parents of Adolescents (SIPA); Sheras, Abidin, & Konold, 1998), suggesting that the index scores from the BRIEF may also reflect the amount of stress that is present in the home (Fitzgerald, Kichler, Moss, Coffey, Heinen, & Kaugars, 2012). In the regressions assessing the prediction of adherence, it is possible that the composite scores from the BRIEF accounted for much of the same variance as T1DM-related conflict scores, and as such, conflict was not a significant predictor of adherence.

Moderations Predicting Treatment Adherence

The third hypothesis in the present study examined several models assessing parental monitoring and involvement in T1DM care as potential moderators of the relationship between adolescents' executive functioning and treatment adherence. Results indicated that parent-reported involvement served as a significant moderator of this relationship, and adolescent-reported parental involvement represented a trend towards statistical significance as a moderator. Further examination of these interactions indicated that that the impact of adolescents' executive functioning on their illness management was stronger for adolescents who had lower levels of parental involvement with their T1DM care. These analyses suggest that perhaps in situations where parents are less involved in adolescents' T1DM management, well-developed executive functioning abilities may serve as a protective factor for those youth, who have better developed cognitive abilities, and as such are able to manage the multiple demands of a complex T1DM treatment regimen. As might be expected, adolescents who demonstrated the lowest levels of treatment adherence were those youth with poorly developed executive functions who also had parents who were not very involved in T1DM care. In contrast, adolescents who displayed the highest levels of treatment adherence tended to have well-developed executive functions but had parents were not very involved in adolescents' illness management. This finding suggests that perhaps there is a subgroup of adolescents with well-developed executive functions for whom a higher level of independent management is advantageous. It is possible that these youth may possess many of the skills necessary to autonomously care for their illness, and when parents are less involved there is less parent-adolescent conflict, and better adherence to treatment.

Parental Involvement vs. Parental Monitoring

Assessment of parental contributions in the illness management of children and adolescents has largely focused on measurements of instrumental involvement with care tasks and parental monitoring (i.e. parent oversight of care tasks). Parental involvement and monitoring behaviors were both assessed in the present study and each came out as a unique predictor in analyses of separate hypotheses. In analyses examining the prediction of adolescent treatment adherence, *parental monitoring* was a significant predictor in the final model; parental involvement did not contribute a significant amount of unique variance at any step of the regressions. However, in the moderational models described above, which assessed parental involvement and monitoring as moderators to the relationship of adolescents' adherence and executive functioning, it was the amount of parents' *instrumental involvement* that served as a significant moderator, rather than parental monitoring. The findings from analyses of these two hypotheses suggests that parental oversight and behavioral monitoring are important in aiding adolescents in managing their illness regimen; however, for adolescents who have poorly developed executive functions, parental monitoring may not be sufficient. Rather, these youth may benefit more from a higher level of instrumental task support and an increase of shared management with parents. Although there has been much research describing the benefits of parental involvement and monitoring as important aspects of T1DM management, there is not much research to suggest who is most likely to benefit from each. Most adolescents with T1DM may benefit from, and are able to maintain acceptable levels of adherence with parental monitoring of their care tasks; however, there is evidence to suggest that for those adolescents with poorer executive functioning abilities, they may derive greater benefit from a more hands-on approach from their caregivers.

Relationship of Adherence and Metabolic Control

There were few significant associations in the present study with the measure of metabolic control (HbA_{1c}), which was proposed as an outcome variable in two of the study hypotheses. Parent and adolescent reports of adherence on the SCI-R and blood glucose record data were significantly correlated with HbA_{1c}, which suggests that adolescents who were more adherent to their treatment regimen did in fact demonstrate better metabolic control. This type of finding offers validity to the measures of adherence, given that HbA_{1c} values are believed to reflect the average blood glucose values from the previous 6-8 weeks. Previous research has demonstrated a significant relationship between the measure of adherence used in the present study (SCI-R) and HbA_{1c} values among children and adolescents with T1DM (Kichler, Kaugars, Maglio, & Alemzadeh, 2012; Weinger et al., 2005). The present study finds continuing support for the relationship between adherence, as assessed by the SCI-R, and a measure of metabolic control. Research aimed at the prediction of HbA_{1c} values can be challenging, given that there are many other factors beyond adherence that contribute to adolescents' metabolic control. These include but are not limited to the influx of insulin resistant hormones that are secreted as a result of illness or pubertal development (Moreland, Tovar, Zuehlke, Butler, Milaszewski, & Laffel, 2004) and psychosocial issues such as depression (Grey, Whittemore, & Tamborlane, 2002), which were variables not assessed in this study. Future research should explore the complex associations among executive functioning, adherence, and HbA_{1c}. For example, consistent with a recent study examining these constructs among a sample of children, perhaps treatment adherence mediates the relationship between executive functioning and glycemic control (McNally et al., 2010). Given the results from the moderational models in the present study, mediated moderation analyses should be explored to examine whether parental involvement serves a moderating role to the association of executive functioning and adherence in a mediation model predicting adolescents' metabolic control.

Performance-based vs. Questionnaire Measures of Executive Functioning

The present study offers several unique contributions to the literature on adolescent T1DM management, primarily with data assessing parent and adolescent report measures of executive functioning abilities. In general, there were few significant relationships among the outcome variables and neuropsychological measures of executive functioning at a bivariate level. As such, the multivariate analyses were conducted with self-reported executive functioning variables and not with the neuropsychological data. There is a paucity of research exploring the convergent validity of self-reported and neuropsychological measures of executive functioning. The few studies that have assessed this relationship utilizing samples of children with traumatic brain injury, phenylketonuria (PKU), frontal lobe lesions, and hydrocephalus have found very few significant relationships between index scores from the BRIEF and performance-based tests of executive function (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Vriezen & Pigott, 2002).

This lack of association between self-report and performance-based measures would suggest that these measures may be assessing different constructs within the executive functioning domain, despite the general assumption that they are measuring similar executive behaviors. As reviewed earlier, one of the primary challenges in assessing executive functioning is that it is a complex and multidimensional construct, and there continues to be debate among researchers as to most effective way to measure it (Wilcutt et al., 2005). A number of possible explanations may be advanced to account for the lack of significant associations among the performance-based measures of executive functioning and self-report questionnaires. One explanation is that performance-based neuropsychological measures of executive functioning may lack sufficient ecological validity and the sensitivity to assess the diverse nature of situations that are experienced in daily life (Barkley & Fischer, 2011). Performance-based measures are typically administered in structured clinical settings and often utilize tasks that do not resemble the types of complex problem solving and mental flexibility involved in the real world. Rating scales assessing executive functions may have an advantage given that they have the capacity to collect information from multiple respondents who can assess the child's abilities in diverse settings over a longer period of time.

Another possible explanation for the difference in findings between the performance and questionnaire measures of executive functioning is that questionnaire measures may be better able to assess the social-cognitive aspects of executive functioning as compared to neuropsychological measures. Although both types of measures are able to assess behavioral aspects of executive function including impulsivity, problem solving, monitoring, and regulation of performance, there are key aspects inherent to most models of executive functioning (e.g., Lezak, 1995) that are more difficult for performance-based measures to assess. Some of these socially-mediated aspects of executive functioning include assessment of motivation, volition and human will, intentionality, and self-awareness (Barkley & Fischer, 2011). Rating scale measures likely offer a more accurate assessment of these aspects and thus may give a more comprehensive picture of executive functioning ability.

As reviewed earlier, most of the significant relationships found between our constructs of interest (i.e. treatment adherence and metabolic control) and executive functioning measures, were found with the parent and self-report measures of executive functioning, rather than with the neuropsychological measures. It is possible that the types of tasks required for managing a diabetes regimen are better assessed by questionnaire measures. With respect to the ecological validity of the neuropsychological measures, perhaps negotiating a card sorting or puzzle task does not approximate the types of cognitive flexibility and problem solving that are involved in managing T1DM. Management of T1DM in daily life is in many ways a “high-stakes” and emotionally salient activity that has real-world health consequences for the individual. Consequently, the neuropsychological assessment tools may not mimic this type of “hot” cognition, which occurs when an individual is interactive and emotionally invested in the task. In general, self-report measures are more likely to account for adolescents’ behavior across multiple settings and may assess some of the social cognitive aspects of executive functioning, which are likely important for managing an illness like T1DM that is typically cared for in a family context. Conversely, it is also possible that we found more significant relationships using our parent and self-report measures of executive functioning due to issues with common method variance between the BRIEF and our primary measure of adherence (i.e. SCI-R).

Neuropsychological Sequelae of Early Onset Diagnosis

Another interesting finding in the current study, which was not consistent with prior research was the lack of significant neurocognitive differences found between our samples of adolescents who were diagnosed early in life (prior to age 7) and those diagnosed at a later age. Previous research suggests modest effect size differences in several aspects of cognitive functioning, including executive functioning and attention in youth with T1DM, when comparing adolescents diagnosed early in life as compared to during the school-age period (Gaudieri et al., 2008). According to Ryan's (2006) diathesis hypothesis, neurocognitive deficits in attention and executive functioning that are seen in youth diagnosed at an early age are primarily due to chronic hyperglycemia that occurs during critical periods of development, which may create structural and functional changes to the CNS and leave the brain vulnerable to later insults. In the current study we did not assess for the frequency and/or severity of hyperglycemia or hypoglycemia experienced. It is possible that we did not have a large enough sample to detect these effects, which typically are modest, and do not represent gross neurocognitive dysfunction.

Clinical Implications

The present research study findings have several potential clinical implications that may play a role in improving the illness management of adolescents with T1DM. Overall, the study finds support for measuring executive functioning abilities in adolescents with T1DM as a potentially important contributing factor in aiding adolescents with the complex management of this illness. Given that the study found significant relationships among self- and parent-reported measures of executive functioning and our measures of adherence, it may be of benefit to administer a measure such as the BRIEF and/or BRIEF-SR to families in periodic clinic visits. This type of assessment would likely be most beneficial in early adolescence as parents and adolescents are beginning to transition illness care responsibilities. The present study would suggest that this brief assessment may offer insight to identify those adolescents in need of additional parental support. Parents are often less willing to provide additional support to older adolescents based on the belief that as emerging adults they need to learn to be autonomous in their management (Palmer et al., 2004). This study suggests that perhaps there is a subgroup of adolescents who have poorer executive functioning and who may benefit from a higher level of shared management. Additionally, well-developed executive functions may serve as a protective factor for adolescents in situations where parents are somewhat disengaged from illness management and who are not able or not willing to offer much support.

Limitations and Future Directions

There were several limitations to the current study, which may limit the generalizability of the findings. One of the limitations was that the study was a cross-sectional design and thus represents only a snapshot of adolescents' cognitive functioning, treatment adherence, and responsibility sharing of diabetes care; therefore, the results describe relationships among variables and not causality. For example, it is not clear from the data whether adolescents have a difficult time adhering to a complex diabetes regimen because they have poorly developed executive functions or whether chronic non-adherence has an effect on the development of adolescents' executive functioning abilities. Additionally, with a cross-sectional design it is unclear how parents adjust their involvement in children's and adolescents' diabetes management over time as adolescents develop more advanced problem solving abilities. A longitudinal study that examines these processes over time would be advantageous and would give a more accurate picture of the evolving process of shared family management. Miller et al. (2012) conducted a longitudinal study examining changes in executive functioning among children (ages 9-11) and found that the Behavioral Regulation Index on the BRIEF predicted changes in treatment adherence over a two- year period. Given the marked frontal lobe and executive functioning development that has been found to occur over the course of adolescence, similar longitudinal research with a sample of adolescents would provide important information to better understand self-care and transition into emerging adulthood. To the best of our knowledge, there has not been much research exploring the role of cognitive functions in the transition that occurs from pediatric to adult care, which is an area that is gaining increasing attention in the literature.

Another limitation of the current study was that the sample was largely Caucasian and middle to upper class socioeconomic status. The percentage of Caucasian families is somewhat higher than the percentage in the CHW diabetes clinic population (85%

Caucasian). Some differences in family and cognitive functioning were noted among ethnically diverse adolescents, compared to the Caucasian adolescents in our study; however, given the largely homogenous nature of the sample, there was not enough statistical power to further explore these effects. Consequently, the generalizability of our findings to populations with different demographic characteristics is limited. Future research in this area should examine these questions with a more diverse sample with respect to ethnicity and socioeconomic status.

An additional limitation to the study design includes the reliance on self-report questionnaires to measure many constructs including the assessment of parental involvement and monitoring, parent-adolescent conflict, and adolescents' mental health. As reviewed earlier, there are issues with common method variance for many of the significant findings in the current study. Another limitation in the current study is that multivariate analyses examined the self-report data within-reporters, meaning that regressions were conducted separately with parents' and adolescents' data. Further analyses should be conducted examining similar predictive models across reporters and utilizing dyadic analyses to account for the perspectives of multiple responders.

Given the integral role that executive functions play in ADHD, the study would likely have benefited from a more thorough assessment of ADHD symptomology, rather than reliance on parent-report of diagnosis (Barkley & Fischer, 2011). A diagnostic measure of ADHD symptoms would provide a more accurate assessment of the presence of this diagnosis. Adolescents with ADHD are at greater risk for experiencing executive dysfunction and consequently may benefit from early identification of symptoms and additional assistance with T1DM management. In the current study, about 9% of participants were identified as having diagnoses of ADHD, which is generally consistent with population base rates, and as such, they were included in analyses. They were included in analyses to were included in analyses Similarly, research suggests that adolescents with T1DM are more likely than healthy adolescents to be diagnosed with depression and anxiety (Grey et al., 2002), which have been associated with poorer treatment adherence and metabolic control (Dabadghao, Vidmar, & Cameron, 2001). Measurement of these constructs would have offered a more comprehensive assessment in the prediction of adolescents' treatment adherence and metabolic control. Additionally, depression and anxiety often have an adverse effect on attention and concentration, which on formal testing, may be mistaken as an deficit in executive functioning ability.

Conclusion

In conclusion, the results of the current study find support for the association between parent- and self-reported executive functioning and treatment adherence among adolescents with T1DM. Specifically, parental involvement was found to be a significant moderator of the relationship between adherence and executive functioning, suggesting that adolescents' executive functioning had a greater impact when parents were less involved in adolescents' illness care. This finding suggests that it may be important for healthcare professionals to assess adolescents' executive functioning abilities in order to identify those youth who may be in the most need for continued parental involvement. Specific targets of intervention could focus on improving adolescents' problem solving and planning abilities to assist youth in developing some of the skills that appear to be necessary for successful T1DM management. Future longitudinal research will be important to assess the developmental trajectory of executive functioning abilities to determine the ways that parents and adolescents negotiate shared management of T1DM care across the adolescent years.

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