ATTENTION PROBLEMS AS A PREDICTOR OF TYPE 1 DIABETES ADHERENCE AND METABOLIC CONTROL ACROSS ADOLESCENCE

by

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ABSTRACT

Management of type 1 diabetes (T1D) is a difficult self-regulatory process that involves adherence to a demanding daily regimen and thus requires continued attention to detailed management behaviors. Youth with attention problems are likely to struggle with the complex tasks involved in diabetes management. The purpose of the present study was to examine the role of attention problems as a predictor of diabetes adherence and metabolic control across time during adolescence and whether parental involvement moderated these associations. Given that past research has excluded attention problems as a predictor of diabetes outcomes or failed to account for other related externalizing behaviors, a secondary goal was to compute a measure of attention problems controlling for other externalizing behaviors. Adolescents with type 1 diabetes (*M* age = 12.49 years, *SD* = 1.53) and their mothers (N = 199) reported on adolescent adherence, attention problems, rule breaking, and aggressive behaviors at three time points, 6 months apart. Youth also completed self-reports of their parents' diabetes-specific monitoring and behavioral involvement. Metabolic control was measured via HbA1c collected from medical records. Adolescent report of attention problems was related to adherence across time, such that more attention problems related to lower levels of adherence over time. Youth and mother report of attention problems at time 1 related to Hba1c at time 1, and mother report also related to her report of time 1 adherence. Mothers' pure attention problems measure at time 1 related to their report of youth adherence at time 1.

Adolescent-reported mothers' diabetes monitoring and parental behavioral involvement with diabetes at time 1 moderated the attention problems/adherence association at time 1. Parents' behavioral involvement with diabetes moderated the association between youth-reported pure attention problems and adherence at time 1. The results of the current study demonstrate that the assessment of adolescent attention problems in the context of type 1 diabetes is an important practice that may help explain poor adherence. The intersection of attention problems and type 1 diabetes management represents an important area for future study, with implications for intervention with youth and their families.

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INTRODUCTION

Management of a chronic illness like type 1 diabetes (T1D) is a difficult self-regulatory process that involves adherence to a complex and demanding daily regimen. Regular disease management behaviors require attention to detail, such as remembering to check blood glucose levels, calculating consumed carbohydrates, and administering correct dosages of insulin based on blood glucose and carbohydrate counts (Hood, Peterson, Rohan, & Drotar, 2009). Forgetting or miscalculating these disease-specific tasks may engender poor metabolic control, which can subsequently lead to short- and long-term health complications (American Diabetes Association, 2011). Adolescents encounter unique developmental challenges and distractions that influence their ability to successfully manage their illness. Hormonal changes during puberty may reduce adolescents' insulin sensitivity and thus require additional focus and planning to maintain glycemic control (Amiel, Sherwin, Simonson, Lauritano, & Tamborlane, 1986; Tfayli & Arslanian, 2007). Additionally, some youth may become wholly responsible for their diabetes care before they are developmentally equipped to manage their illness independently (Greening, Stoppelbein, & Reeves, 2006; Helgeson, Reynolds, Siminerio, Escobar, & Becker, 2008; Iannotti & Bush, 1993; Wysocki, Greco, & Buckloh, 2003). Thus, especially during adolescence, youth must draw on a variety of self-regulatory resources (such as attention) to complete illness-related tasks in the moment and over the long-term in the service of effective management.

Youth with attention problems are likely to struggle with the self-regulatory tasks involved in diabetes management as they often grapple with other multifaceted regulatory tasks such as school work, managing responsibilities at home, and peer interactions (Pelham et al., 2005). Faculties in attention allow individuals to assess their environments, maintain focus on a task, and shift that focus to other competing demands when necessary, crucial processes for success on complicated self-regulatory tasks (Compas & Boyer, 2001; Cooley & Morris, 1990). Difficulties in attention may impede adolescents' capacity to plan for the future, organize their thoughts and priorities, and persevere through tasks and activities, with deleterious effects on continuing regulatory obligations (Compas & Boyer, 2001). For example, adolescents with T1D and deficits in attention may often forget their diabetes supplies at home or get distracted and overlook necessary blood glucose tests or insulin injections. Thus, the symptoms of attention problems directly contradict the skills and considerations required to manage a complex chronic illness like diabetes (Sanchez, Chronis, & Hunter, 2006).

Support for the Examination of Attention Problems and Diabetes Outcomes

Although attention has been relatively unexplored in the pediatric diabetes literature, research on related constructs (e.g., externalizing behavior, executive function, self-control) is consistent with the idea that attention problems may be a risk factor for poor adherence and metabolic control in adolescents. Attention issues, in addition to rule breaking and aggressive behavior, are regarded as facets of externalizing behaviors, linked by similarities in impulsivity, disruptive behavior, and defiance (Burt, Krueger,

McGue, & Iacono, 2001; Hinshaw, 1992). Previous studies have established that externalizing behaviors are associated with poorer regimen adherence and glycemic control (Cohen, Lumley, Naar-King, Partridge, & Cakan, 2004; Duke et al., 2008; Naar-King et al., 2006). Notably, Northam, Matthews, Anderson, Cameron, and Werther (2005) found that adolescents with preexisting behavior problems at their diabetes diagnosis demonstrated poorly controlled diabetes up to 10 years later.

These facets of externalizing behaviors (i.e., rule breaking and aggressive behavior) have been shown to co-occur with attention problems in normative samples (Jester et al., 2005; Langberg et al. 2011; Wang, Deater-Deckard, Petrill, & Thompson, 2012); however, there is evidence to suggest that these behaviors represent distinguishable constructs with distinct trajectories and life outcomes (Fergusson & Horwood, 1995a; Fergusson, Boden, & Horwood, 2010; Hinshaw, 1987). Although rule breaking, aggressiveness, and attention problems may share the element of impulsivity, factor analyses and phenotypic studies have differentiated these concepts (Fergusson & Horwood, 1995b; Hinshaw, 1987; Nadder, Silberg, Rutter, Maes, & Eaves, 2001; Rapport, Scanlan, & Denney, 1999). Additionally, whereas aggression and delinquency normatively decline across adolescence (Jester et al., 2005; Steinberg, 2005, 2008; Zhou et al. 2007), some adolescents may experience stable or increased attention problems across development that put them at greater risk for nonadherence (Biederman, Mick, & Faraone, 2000**;** Zhou et al. 2007). Additionally, adolescents with attention problems show more academic and neurocognitive deficits when compared to their healthy (Aman, Roberts, & Pennington, 1998; Andersen, Egeland, & Oie, 2013) and conduct disordered (Fergusson et al., 2010; Langberg et al. 2011) peers. Thus, adolescents with attention

problems may lack the core cognitive abilities required to manage a complex illness regimen, whereas their aggressive or rule-breaking counterparts may not.

Although the psychopathology literature has differentiated the externalizing behavior constructs, few studies in the diabetes literature have done the same. Distinguishing facets of externalizing behaviors is important because attention problems, rather than rule breaking or aggressive behavior, could emerge as the relevant component for diabetes management. However, studies have collapsed attention problems into externalizing behaviors as predictive of diabetes outcomes (Liss et al., 1998; Naar-King et al., 2006), excluded attention problems altogether (Cohen et al., 2004; Duke et al., 2008; Luyckx, Seiffge-Krenke, & Hampson, 2010), or examined attention problems without controlling for other facets of externalizing behaviors (Leonard et al., 2002; 2005). A primary goal of this study was to examine attention problems as its own subscale as well as to compute a measure of attention problems controlling for other externalizing behaviors.

Further, previous cross-sectional studies that have explicitly examined attention problems have left various questions unanswered regarding the association between attention problems and diabetes management across adolescence. In the two studies that explicitly examined the Attention Problems subscale of the Youth Self Report, Leonard et al. (2002, 2005) found that higher attention problems, rule breaking, and aggressive behavior was each related to worse metabolic control. However, the authors did not examine these behaviors as related to diabetes adherence, the intermediate behavioral process associated with metabolic control. Moreover, both of these studies were cross-sectional in nature, and no other known studies have examined the association of

attention problems and diabetes outcomes across the period of adolescence, when we know responsibility for diabetes care shifts toward adolescents (King, Berg, Butner, Butler, & Wiebe, 2014). Further, the Leonard et al. (2002, 2005) studies used child self-reported attention problems and did not include child and parent report concurrently, an approach that could provide a more complete picture of these processes in adolescence. On the one hand, research on reporter accuracy of externalizing behaviors and ADHD symptoms has demonstrated that parent or teacher report of youth's externalizing and attention problems may be more reliable than adolescent self-report of the same symptoms (Hoza et al., 2004; Smith, Pelham, Gnagy, Molina, & Evans, 2000; Youngstrom, Loeber, & Southam, 2000). On the other hand, however, research has suggested that as youth mature, they may possess unique information about their daily environment and management behaviors unbeknownst to their parents (Ellis et al., 2012; Lehmkuhl et al., 2009) and may more accurately be aware of their attention difficulties. Thus, the inclusion of both parent and child report at multiple time points will allow comparisons of the attention problems/diabetes adherence link across reporters.

Greater Parental Involvement May Compensate for Attention Problems

Given the challenges with diabetes adherence that youth with attention problems may experience, such youth may profit from supplemental outside help from parents to successfully complete adherence behaviors. First, case study findings from Sanchez, Chronis, and Hunter (2006) suggest that increased parental monitoring of and involvement with diabetes tasks may improve adolescent adherence behaviors and

metabolic control among children with ADHD. Second, studies in the ADHD literature also support that parental involvement may be especially beneficial for adolescents with attention difficulties (Pelham & Fabiano, 2008). Third, in the diabetes literature, diabetes management during adolescence is often most successful when it involves a collaborative process between parents and youth (Nansel, Iannotti, & Liu, 2012; Wiebe et al., 2005), as sustained parental involvement across adolescence has been associated with better adherence and glycemic control (Berg et al., 2008; Ellis et al., 2007; King et al., 2014). Finally, studies of family processes and attention problems have demonstrated that increased parental monitoring and reinforcement of children's behavior at home (i.e., Behavioral Parent Training) can improve family functioning and the symptoms of ADHD (Pelham & Fabiano, 2008). Family diabetes management may operate differently for adolescents with attention difficulties: caregivers may need to compensate for adolescent inattention through more involvement than is customary during this developmental phase.

The Current Study

The purpose of the present study was to examine the role of attention problems as a predictor of diabetes adherence and metabolic control across time during adolescence, and whether parental involvement moderated these associations. Specifically, this study examined attention problems, adherence, and metabolic control across three time points within a sample of adolescents with T1D. The first aim of the study was to explore the relation of adherence and metabolic control with attention problems over time in adolescents with type 1 diabetes. It was expected that higher levels of attention problems would relate to poorer adherence and metabolic control. The associations between

attention problems with diabetes adherence and metabolic control were also examined for youth versus mother report. The second aim of this study was to examine the role of attention problems and diabetes outcomes with a measure of attention problems that controlled for other externalizing behaviors. It was expected that this more pure measure of attention problems would uniquely relate to diabetes adherence and metabolic control. The third aim was to explore whether the association of attention problems and diabetes outcomes was reduced when parents were more involved and monitored their adolescent's behavior. It was expected that for adolescents with higher levels of attention problems, higher levels of diabetes-specific parental involvement (behavioral involvement and monitoring) would compensate for higher attention problems. We expected the buffering effect of increased parental involvement and monitoring to relate to improved adherence and better metabolic control.

METHOD

Participants

The University of Utah Institutional Review Board approved the study. Adolescents provided written assent, and their caregivers provided written informed consent and parental permission for youth's participation. Participants included young adolescents (*M* age = 12.49 years, *SD* = 1.53, 53.6% females) diagnosed with type 1 diabetes mellitus and their mothers, recruited as part of a larger longitudinal study that included 252 adolescents and mothers. Adolescents and their caregivers were recruited from two clinics with equivalent treatment guidelines: a university outpatient diabetes clinic (76%) and a private practice run by a pediatric endocrinologist (24%). Eligibility criteria required children to be 10 to 14 years of age, diagnosed with type 1 diabetes for a minimum of 1 year (*M* = 4.13 years, *SD* = 3), living with their mother, and able to read and write either English or Spanish. Families were by and large Caucasian (94%) and middle class. Most families (73%) reported household incomes that averaged $50,000 or more annually, 51% of mothers and 58% of fathers reported associate's (2-year college) degrees or beyond and an average Hollingshead Index score of 42.04 (average medium business, minor professional, or technical status). The measures included in the current study were administered at three time points, spaced at 1-year intervals as part of a larger longitudinal study. Time 1 included 250 adolescents and 251 mothers, time 3 included 189 adolescents and 195 mothers, and time 5 included 177 adolescents and 182 mothers.

However, of these total participants, only dyads that had both mother and youth data at two time points or more (any combination of times 1, 3, and 5) were included in analyses (N = 199).

Materials and Procedure

Participants were recruited during their regular medical appointment at either of the two participating clinics. Adolescents and their caregivers reported on youth psychosocial adjustment, and adolescents reported on parents' behavioral involvement with diabetes using take-home survey measures; participants were instructed to complete the measures individually and away from others in the home. Adolescents also completed a measure of mothers' and fathers' diabetes monitoring as part of the take-home survey packet. Dyads completed additional measures during their subsequent study visit in clinic, which included a measure of adherence.

Measures

Youth and Mother Report of Attention Problems, Rule Breaking, and Aggressive Behaviors

Attention problems, rule breaking, and aggressive behaviors were measured using adolescents' self- and mothers' report on the Youth Self-Report (YSR; Achenbach, 1991) and Child Behavior Checklist (CBC-L; Achenbach, 1991), respectively. For all items, respondents rated whether the behavior was not true (0), somewhat or sometimes true (1), or very true or often true (2) over the prior 6 months. The Attention Problems subscales included items that assessed inattentiveness, impulsivity, and hyperactivity, the core

components of Attention Deficit/Hyperactivity Disorder as described in DSM IV-TR (American Psychiatric Association, 2000). Adolescents' alphas ranged from .80 to .83, and mothers' ranged from .85 to .88 across the three time points. This subscale relates to structured-interview diagnoses of ADHD (Chen, Faraone, Biederman, & Tsuang, 1994). The Rule Breaking subscales included 15 items related to lying, stealing, substance use, and interacting with deviant peers. Adolescents' alphas ranged from .76 to .83, and mothers' ranged from .76 to .81. The Aggressive Behaviors subscale included items related to anger, bullying, and unstable moods. Adolescents and mothers demonstrated good reliability on this subscale; alphas ranged from .86 to .88 for adolescents and from .88 to .92 for mothers. Due to the nonclinical nature of the current sample and the truncated variability that may accompany the use of T-scores, we used raw scores[1] for all subscales in the final analyses as suggested by Drotar, Stein, and Perrin (1995). Raw scores were summed to create a total score for each reporter for each specific subscale.

Parental Monitoring

A diabetes-specific subscale measured the construct of monitoring and demonstrated excellent reliability in the current sample (alphas ranging from .80 to .91). On five items, adolescents rated their mothers and fathers separately on amount of diabetes-specific knowledge (Berg et al., 2008). Responses on this subscale ranged from 1 ("doesn't know") to 5 ("knows everything"). An average score was calculated for each subscale for each reporter.

[1] T-scores were also tested in analyses without significant change in results.

Parental Involvement

Adolescents rated who was responsible for 23 diabetes management tasks (e.g. "Who determines the insulin dose?") on a 1 to 5 (1 = "Child does it alone," 3 = "Child and parent share equally," 5 = "Parent does it alone") scale using the Diabetes Responsibility Scale (Rubin, Young-Hyman, & Peyrot, 1989). The original measure was updated to include items related to current insulin regimens with the help of a Certified Diabetes Educator. Insulin administration items that previously only applied to conventional regimens (i.e., injections) were modified to reflect insulin pump regimens as well. Both the initial (Rubin et al., 1989) and modified versions of this scale demonstrate high reliability (α = .92 in this study).

Adherence

Adolescents and mothers completed a 16-item modification of the Self Care Inventory (adapted from La Greca et al., 1995) to assess adolescent adherence to the diabetes regimen over the preceding month (1 = "never did this" to 5 = "always did this as recommended without fail"). Items reflected contemporary standards for diabetes management related to insulin administration, blood glucose checking, diet, and exercise. Scores on this scale have good internal consistency (α = .86 at all time points) in our sample and correlate well with other more time-intensive interview methods for measuring adherence (La Greca et al., 1995).

Metabolic Control

Metabolic control was measured by glycosylated hemoglobin percentages (HbA1c) at participants' routine medical appointments by clinic staff. All clinic sites

used the Bayer DCA 2000 method to calculate HbA1c. HbA1c is a measure of average blood glucose over the preceding 2 to 3 month period (American Diabetes Association, 2013). Lower HbA1c values indicate better glycemic control. Additionally, participants provided written consent to allow study staff access to adolescents' medical records to obtain HbA1c values and other health information (e.g., height, weight, duration of diabetes, mode of insulin administration). The mean HbA1c for this study was 8.31% (*SD* = 1.40).

Data Analysis Plan

Separate hierarchical linear models were conducted for adolescent and mother data using HLM 7 (Raudenbush, Bryk, Cheong, Congdon, & de Toit, 2011). Time varying covariate models were employed at level 1 to examine the association of adherence and metabolic control with attention problems at each of the three time points (Aim 1). Attention problems were group centered, and time 1 was centered at zero. Additionally, in an attempt to capture the relation between attention problems and diabetes outcomes at time 1, grand centered attention problems at time 1 were used at level 2 (predicting the intercept at level 1), with attention problems at time 1 also entered as a moderator of the time effect at level 1. Because time 1 was centered at zero, this made it so that the coefficient γ_{02} represented how time 1 attention problems were associated with time 1 adherence. In all models, we did not allow for random effects on attention problems in order to be overspecified in terms of model specification. Finally, at level 2, pump status (1 = using a pump) and time since diabetes diagnosis (in number of months) were included as covariates, as such variables frequently related to both

metabolic control and adherence.

Level-1 Model

$$\text{Adherence}_{mj} = \psi_{0j} + \psi_{1j}(\text{Attention Problems}_{mj}) + \psi_{2j}(\text{Time}_{mj}) + e_{mj}$$

Level-2 Model

$$\psi_{0j} = \gamma_{00} + \gamma_{01}(\text{Pump Status}_{j}) + \gamma_{02}(\text{T1 Attention Problems}_{j}) + \gamma_{03}(\text{Time Since Dx}_{j}) + u_{0j}$$

$$\psi_{1j} = \gamma_{10}$$

$$\psi_{2j} = \gamma_{20} + \gamma_{21}(\text{T1 Attention Problems}_{j}) + u_{2j}$$

In order to get a measure of attention problems that was separate from other facets of externalizing behaviors (e.g., rule breaking, aggressive behaviors), we examined the unique prediction of attention problems (Aim 2). To do this, we first conducted a hierarchical linear model predicting attention problems from rule breaking and aggressive behavior. The residuals from this equation (or the unique contribution of attention problems unrelated to rule breaking and aggressive behavior) were then saved out and were used to predict adherence and metabolic control across time in time-varying covariate models. The same level 2 model (described above) was conducted examining pump status and duration of diabetes as covariates and pure attention problems at time 1 predicting adherence at time 1.

To address Aim 3, we ran 12 (2 forms of attention problems x 3 types of parents' diabetes involvement x 2 diabetes outcomes) separate hierarchical models to test for the moderating effects of parenting on attention problems in predicting adherence and HbA1c. Specifically, we tested the interaction of adolescent-reported attention problems (2; both the original YSR subscale and the "pure" measure) with adolescent-reported

parents' diabetes involvement (x 3; report of both parents' behavioral involvement with diabetes, mothers' diabetes monitoring, and fathers' diabetes monitoring) predicting diabetes outcomes (x2; adherence and HbA1c). We input adolescent-reported attention problems across time and time point in the study into level 1 as predictors of adherence (and metabolic control). We created interactions in SPSS between grand mean centered time 1 attention problems x time 1 parental involvement and attention problems x diabetes monitoring (also grand centered and at time 1). Then we entered these interactions (and their main effects) on the intercept at level 2 as moderators of the attention problems/adherence (attention problems/metabolic control) relationship. We also entered the interaction and main effect terms on the time variable (ψ_{2j}), so that the coefficient of the interaction on the level 2 intercept represented how time 1 attention problems x time 1 parental involvement was associated with time 1 adherence (and metabolic control; see model provided below).

Level-1 Model

$$\text{Adherence}_{mj} = \psi_{0j} + \psi_{1j}(\text{Adolescent Attention Problems}_{mj}) + \psi_{2j}(\text{Time}_{mj}) + e_{mj}$$

Level-2 Model

$$\psi_{0j} = \gamma_{00} + \gamma_{01}(\text{Time Since Dx}_{j}) + \gamma_{02}(\text{T1 Adolescent Attention Problems }_{j}) + \gamma_{03}(\text{T1 Parents' Diabetes Involvement}_{j}) + \gamma_{04}(\text{T1 Attention Problems x T1 Diabetes Involvement}_{j}) + \gamma_{05}(\text{Pump Status}_{j}) + u_{0j}$$

$$\psi_{1j} = \gamma_{10}$$

$$\psi_{2j} = \gamma_{20} + \gamma_{21}(\text{T1 Adolescent Attention Problems}_{j}) + \gamma_{22}(\text{T1 Parents' Diabetes Involvement}_{j}) + \gamma_{23}(\text{T1 Attention Problems x T1 Diabetes Involvement}_{j}) + u_{2j}$$

RESULTS

Preliminary Analyses

Descriptive statistics and zero-order correlations among study variables were examined at all time points for this study (1, 3, and 5). Adherence and HbA1c were moderately correlated (r = -.31, -.25 -.41). At times 1, 3, and 5, adolescent and mothers' report of adolescent attention problems were each associated with their respective report of adherence (r's for adolescent range from -.16 to -.42; r's for mom range from -.25 to -.36). Adolescent report of attention problems was significantly correlated with HbA1c at times 1 (r = .24, p = <.001) and 3 (r = .17, p = .02) and trended toward significance at time 5 (r = .11, p = .17). Mothers' report of adolescent attention problems was significantly related to HbA1c at time 1 (r = .22, p = <.001) and trended toward significance at times 3 (r = .10, p = .17) and 5 (r = .14, p = .06). At all time points, attention problems as reported by both adolescents and mothers were significantly correlated with rule breaking (r's for youth range from .41 to .58; r's for mom range from .58 to .60) and aggressive behaviors (r's for adolescents range from .67 to .76; r's for mother range from .65 to .69). Adolescents' and mothers' reports of attention problems were moderately correlated at all time points (r's range from .38 to .40). At time 1, both reports of attention problems were positively associated with youth report of parental involvement (adolescent: r = .19, p = .002; mom: r = .14, p = .03), and adolescents' report of attention problems was also related to their report of fathers' diabetes

monitoring (r = -.14, p = .04).

Association of Attention Problems and Diabetes Outcomes Over Time

To examine whether adherence and HbA1c were associated with attention problems over time (Aim 1), separate HLM analyses were conducted predicting adherence and HbA1c from youth and mother report of attention problems, controlling for study time point, time since diagnosis, and pump status. Table 1 includes the results of these analyses. Adolescent report of attention problems was related to adherence across three time points, such that more attention problems related to lower levels of adherence over time. When controlling for the level 1 effect, the association between time 1 attention problems and time 1 adherence was not significant, but trended in the appropriate direction.

Adolescent report of attention problems over time was not related to HbA1c over time. Conversely, adolescent attention problems at time 1 did predict metabolic control at time 1, such that more attention difficulties related to poorer (higher) HbA1c at the first time point.

Mothers' report of adolescent attention problems over time was not related to her report of adolescent adherence nor to HbA1c over time. In contrast, mothers' report of attention problems at time 1 was related to both her report of adolescent adherence and to HbA1c at time 1, reflecting that more attention problems at time 1 related to both poorer management (lower) and metabolic control (higher) at this time point.

Association of "Pure" Attention Problems and Diabetes Outcomes Over Time

To examine whether adherence and metabolic control would be associated with a "pure" measure of attention problems over time (Aim 2), the common variance between attention problems and rule breaking and between attention problems and aggressive behaviors was removed from adolescent and mother report of attention problems. Each reporter's "pure" measure of attention problems was then used in separate HLM analyses to predict adherence and HbA1c. Adolescent pure attention problems were not associated with self-reported adherence across time (b = -.03, SE = .02, t = -1.44, p = .15); pure attention problems at time 1 did not predict time 1 adherence (b = .02, SE = .03, t = .93, p = .36). Adolescents' measure of pure attention problems was not related to metabolic control, either over time (b = -.007, SE = .05, t = -.16, p = .88) or at time 1 (b = .07, SE = .08, t = .99, p = .33).

Similarly, mothers' pure measure of attention problems was not related to her report of adherence across time (b = .01, SE = .02, t = .69, p = .50), but mothers' reports of pure attention problems at time 1 did predict their reports of adolescent adherence at time 1 (b = -.10, SE = .04, t = -2.23, p = .027). Mothers' report of pure attention problems did not relate to HbA1c over time (b = .005, SE = .05, t = .09, p = .93), or at time 1 (b = .03, SE = .12, t = .25, p = .81).

Attention Problems Moderated by Parents' Involvement with Diabetes

To assess whether parental involvement moderated attention problems over time to predict adherence and HbA1c, we examined both the attention problems subscale and the pure measure of attention problems as moderated by adolescent report of total parents' diabetes involvement and each parent's diabetes monitoring. First, we input the adolescent Attention Problems subscale (group centered) across time as a predictor at level 1, along with time. Next, we entered the time 1 interaction term (grand mean centered in SPSS), its main effects, and covariates on the level 2 intercept. The main effect and interaction terms were also entered on the time term at level 2.

Adolescent report of mothers' diabetes monitoring at time 1 was significantly related to time 1 adherence (b = .29, SE = .05, t = 6.40, p = <.001) and also significantly moderated the association between self-reported attention problems and adherence at time 1 (b = .03, SE = .01, t = 2.30, p = .022). Simple slope effects of this two-way interaction were tested at low (-1 SD) and high (+1 SD) levels of time 1 mothers' diabetes monitoring (corresponding to centered values of -.79 and .79) using methods by Preacher, Curran, and Bauer (2006). Figure 1 illustrates simple slopes of the association between attention problems and adherence by mothers' diabetes monitoring. As predicted, for adolescents with low levels of mothers' diabetes monitoring at time 1, higher attention problems were associated with poorer adherence (b = -.04, SE = .01, t = -3.68, p = .0003); however, when mothers' monitoring was high, attention problems were not associated with adherence (b = .005, SE = .01, t = .28, p = .78). Youth-reported mothers' diabetes monitoring did not moderate the association between attention

problems and metabolic control (b = -.009, SE = .03, t = -.29, p = .77). Moreover, youth-reported fathers' diabetes monitoring at time 1 did not significantly moderate the association between time 1 self-reported attention problems on the YSR and adherence (b = -.01, SE = .008, t = -1.52, p = .13) or metabolic control (b = -.01, SE = .02, t = -.47, p = .64).

The association between adolescent attention problems and adherence at time 1 was also significantly moderated by adolescent report of parents' diabetes involvement (b = .03, SE = .01, t = 2.57, p = .011) at time 1. Contrary to the results previously presented for Aim 1, in this model youth reported attention problems at time 1 *were* significantly associated with time 1 adherence (b = -.02, SE = .01, t = -2.0, p = .047). We tested simple slope effects of the two-way interaction at low (-1 SD) and high (+1 SD) levels of time 1 parental involvement (corresponding to centered values of -.62 and .62) using methods by Preacher, Curran, and Bauer (2006). Figure 2 illustrates simple slopes of the association between attention problems and adherence by parents' diabetes involvement. At time 1, when parents were less involved with diabetes, adolescents' attention problems were associated with lower adherence (b = -0.05, SE = 0.01, t = -3.39, p = 0.0008); however, when parental involvement was high, attention problems were not associated with adherence (b = .002, SE = .02, t = .11, p = .91). These findings support the idea that parental involvement moderates the relation between attention problems and adherence.

We then conducted the same HLM moderation analyses as above, substituting the "pure" measure of attention problems in for the YSR Attention Problems scale in the models. Results demonstrated that adolescent report of parental diabetes involvement at time 1 significantly moderated the association between youth-reported pure attention

problems and adherence at time 1 (b = .12, SE = .04, t = 3.06, p = .002). Again using the method of Preacher et al. (2006), simple slope effects were tested at low (-1 SD) and high (+1 SD) levels of time 1 parental involvement with diabetes (corresponding to centered values of -.62 and .62). Figure 3 illustrates simple slopes of the association between pure attention problems and adherence by parents' diabetes involvement. Somewhat surprisingly, for adolescents who perceived their parents as more behaviorally involved with their diabetes at time 1, higher pure attention problems were associated with greater adherence to the diabetes regimen (b = .09, SE = .04, t = 2.47, p = .014); however, when parental involvement was low, pure attention problems were not associated with adherence, although this effect trended in the appropriate direction (b = -.06, SE = .04, t = -1.72, p = .086).

Table 1

Adherence & Metabolic Control Predicted from YSR/CBC-L Attention Problems.

DV: Adherence	Adolescent Report			Mother Report		
	B	*SE*	*t*	*B*	*SE*	*t*
Intercept (γ_{00})	3.98	0.04	107.96***	3.62	0.03	113.21***
Pump Status (γ_{01})	0.16	0.06	2.53*	0.16	0.06	2.68**
Time Since Diagnosis (γ_{02})	-0.001	0.001	-1.62	-0.003	0.001	-3.98***
T1 Attention Problems (γ_{03})	-0.02	0.01	-1.81	-0.04	0.01	-4.78***
Attention Problems (γ_{10})	-0.03	0.01	-3.08**	-0.01	0.01	-1.11
Time (γ_{20})	-0.06	0.01	-4.16***	-0.06	0.01	-6.02***
T1 Attention Problems (γ_{21})	-0.01	0.005	-1.37	0.0001	0.003	0.06
DV: Metabolic Control	Adolescent Report			Mother Report		
	B	*SE*	*t*	*B*	*SE*	*t*
Intercept (γ_{00})	8.33	0.10	87.38***	8.31	0.10	86.30***
Pump Status (γ_{01})	-0.93	0.18	-5.11***	-0.90	0.19	-4.77***
Time Since Diagnosis (γ_{02})	0.01	0.003	1.96	0.01	0.003	1.65
T1 Attention Problems (γ_{03})	0.10	0.03	4.02***	0.07	0.03	2.40*
Attention Problems (γ_{10})	-0.03	0.02	-1.18	0.01	0.02	0.42
Time (γ_{20})	0.18	0.03	6.36***	0.18	0.03	6.49***
T1 Attention Problems (γ_{21})	-0.02	0.01	-1.72	-0.002	0.01	-0.27

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

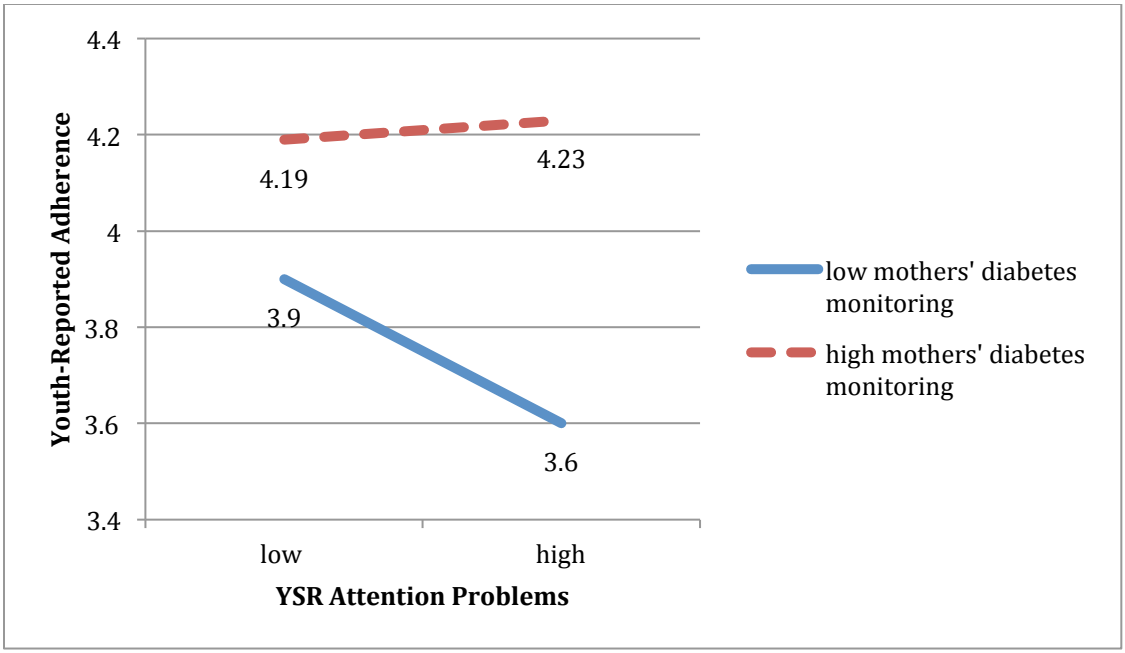

Figure 1

Simple Slopes as a Function of Youth-Reported Mothers' Diabetes Monitoring.

Note. Low and high values of mothers' diabetes monitoring are defined as plus and minus 1 *SD* about the mean (centered values of -.79 and .79). The simple slope of association between youth-reported attention problems and adherence at time 1 is *not* significantly different from zero for those with high mothers' diabetes monitoring; the simple slope for low mothers' diabetes monitoring is significantly different from zero (see text for simple slope estimates and results of significance tests).

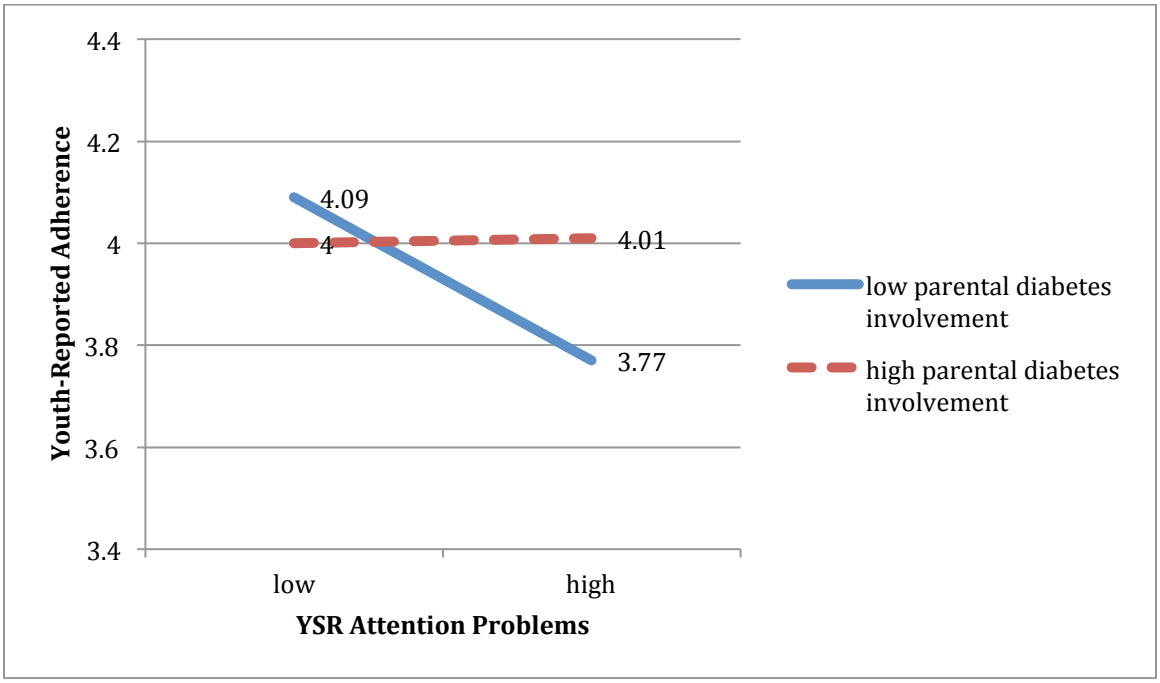

Figure 2

Simple Slopes as a Function of Youth-Reported Parents' Diabetes Involvement.

Note. Low and high values of parents' diabetes involvement are defined as plus and minus 1 *SD* about the mean (centered values of -.62 and .62). The simple slope of association between youth-reported attention problems and adherence at time 1 is *not* significantly different from zero for those with high parental diabetes involvement; the simple slope for low parents' diabetes involvement is significantly different from zero (see text for simple slope estimates and results of significance tests).

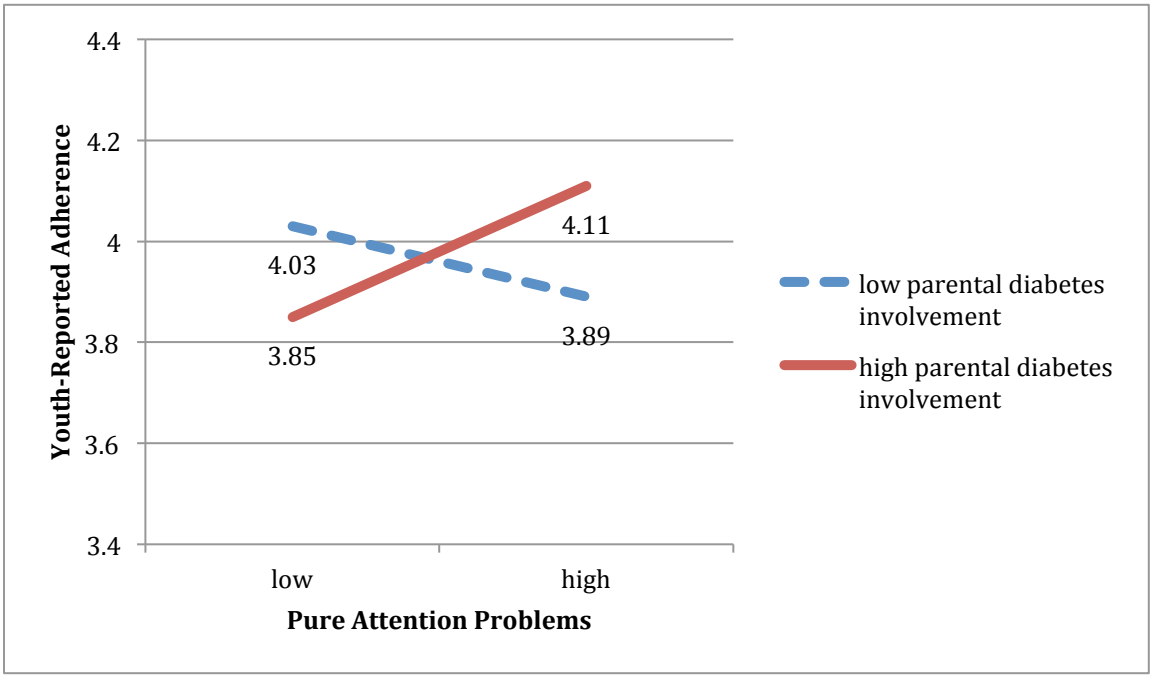

Figure 3

Simple Slopes as a Function of Youth-Reported Parents' Diabetes Involvement (Pure Attention Problems).

Note. Low and high values of parents' diabetes involvement are defined as plus and minus 1 *SD* about the mean (centered values of -.62 and .62). The simple slope of association between Time 1 youth-reported pure attention problems and adherence is *not* significantly different from zero for those with low parental diabetes involvement; the simple slope for high parents' diabetes involvement is significantly different from zero (see text for simple slope estimates and results of significance tests).

DISCUSSION

Overall, results indicated that adolescent attention problems as measured by the YSR/CBC-L Attention Problems subscales related to diabetes outcomes at time 1 and to adherence across time. Specifically, adolescents' self-reported attention problems and adherence were associated over a 2-year period. Adolescents' report of attention problems at time 1 predicted their metabolic control at time 1, indicating that youth who reported higher attention problems during young adolescence were less able to manage their diabetes during that time. Mothers' reports of youth attention problems on the CBC-L were not related to their reports of adolescent adherence or to HbA1c over time in time-varying covariate models. However, mothers' reports of adolescent attention problems at time 1 were significantly associated with their reports of time 1 adherence. It is somewhat surprising that while mothers' reports of attention problems were associated cross-sectionally with adherence and HbA1c at multiple time points, this association did not change over time with adherence and metabolic control (i.e., emerge in multilevel models across time). This finding may reflect adolescents' superior knowledge of their daily management abilities across adolescence and potentially a greater understanding of how their continual management is influenced by lapses in attention compared to their parents' (Berg et al., 2014).

The measure of attention problems that controlled for other externalizing behaviors demonstrated fewer associations with diabetes outcomes than we expected. We

created this "pure" measure of attention difficulties by partialing the shared variance of rule breaking and aggressive behaviors from attention problems and then used this as a predictor of diabetes outcomes. We computed a pure measure in order to capture the unique contribution of inattention on diabetes management and to account for the high correlation observed among externalizing issues (including attention problems). Mothers' reports of adolescents' pure attention problems at time 1 significantly predicted their reports of adolescent adherence at time 1. However, contrary to expectations, neither mothers' nor adolescents' pure measure of attention problems ultimately fluctuated with adherence or HbA1c across time. The lack of association between adolescents' pure attention problems and their report of adherence over time was somewhat surprising given the time-varying association with the YSR Attention Problems subscale. It is possible that the partialing procedure we employed in the current analyses did not result in a real world construct and instead fell prey to the "perils of partialing" (Lynam, Hoyle, & Newman, 2006). Although we wanted to isolate the influence of attention problems from other externalizing behaviors, these behaviors do co-occur frequently in clinical samples of medically healthy adolescents.

It may also be the case that these general psychosocial measures do not fully capture enough ADHD symptom specific criteria. Perhaps if we had used a symptom-specific measure expressly designed to assess attention problems, we would have observed different results. In a sample of older adolescents, Berg et al. (2014) found that the Conners' scales for ADHD were associated with both mother- and adolescent-reported global adherence and adolescent-reported daily adherence, including number of blood sugar checks. Moreover, objective measures of attention problems such as the

Conners Continuous Performance Task (CPT 3; Conners, 2014) may also more effectively capture clinically significant attention problems (and inattention specifically), therefore making it easier to detect associations with diabetes management (Berg et al., in preparation; Suchy et al., in preparation).

Results of the parental involvement moderation analyses were mixed. Simple slopes testing demonstrated that the pattern of moderating effects of parents' diabetes involvement were in the expected direction for the YSR Attention Problems and pure attention problems models. Specifically, time 1 mothers' diabetes monitoring and parents' behavioral involvement with diabetes each significantly moderated the time 1 YSR attention problems/adherence association; in both cases lower levels of parents' involvement (i.e., simple slopes) were significant, such that low involvement at time 1 appeared especially detrimental for adolescents with high attention problems. Additionally, adolescents with high parental involvement and high pure attention problems reported the highest adherence, such that high parental diabetes involvement appeared to compensate for the detrimental effect of attention problems on adherence (per adolescent report). These results are supportive of the idea that parental involvement can compensate for the detrimental effects of attention problems (with and without rule breaking or aggressive behaviors) on adhering to a complex management routine as is required in type 1 diabetes. Overall, specific simple slopes of these moderation analyses suggest that parental involvement with diabetes might be beneficial for youth with high attention problems. However, we strongly recommend caution when interpreting these findings, as these four interactions emerged as significant from a high number of statistical tests.

The results of the present study must be interpreted in the context of some limitations. First, this sample of adolescents was drawn from one site in the western United States, was mostly Caucasian, and was from middle to high socioeconomic backgrounds; results of the current study need to be replicated in a more diverse sample. Second, we are interpreting the association among attention problems and diabetes outcomes in the context of a nonclinical sample. It is possible that the association between attention problems and diabetes management would be more salient in a sample of adolescents with clinically significant attention problems than occurred in the present sample.

Third, the directionality of the effect between adherence and adolescent report of attention problems is unclear. Conclusions in the literature have been mixed regarding the causal direction between cognitive dysfunction and metabolic control. Multiple studies have argued that poor metabolic control leads to cognitive difficulties (attention problems and executive dysfunction; Naguib, Kulinskaya, Lomax, & Garralda, 2009; Rovet & Alvarez, 1997). However, it seems plausible that an underlying vulnerability for attention problems may exist prior to the diagnosis of diabetes (especially for youth diagnosed late) and the resultant influence of glucose variability. To address this question, we controlled for time since diagnosis in all analyses. It is encouraging that we found associations between attention problems and adherence across time and between attention problems and adherence and metabolic control at time 1 despite controlling for this variable.

Finally, the current study solely included subjective report (adolescent and mom report) of youth attention problems and adherence and did not directly assess these

constructs using behavioral or objective measures. Therefore, it is possible that the association between adolescent-reported attention problems and adherence might reflect common method variance. Importantly, however, scores on the Inattention composite of the behaviorally measured Continuous Performance Task (CPT II; Conners, 2000) have been linked to adherence and metabolic control in a sample of older adolescents (Suchy et al., in preparation; Berg et al., in preparation). Further research is needed to ascertain whether the links between attention problems and adherence over time result in clinically significant metabolic outcomes.

Despite its limitations, to our knowledge this study is one of the first to examine the association between attention problems and adherence, especially across time using longitudinal data. Our study is equally novel in its inclusion of both mother and adolescent report of adolescent attention problems and adherence (with the exception of Berg et al., 2014). Finally, this study extended the existing literature in its inclusion of metabolic control and parental diabetes involvement across early adolescence. Examining the associations among these constructs is important, as we know that adherence, metabolic control, and parental involvement typically decline across adolescence and that deteriorations in parental involvement predict subsequent poorer adolescent diabetes outcomes (King et al., 2012, 2014). It is plausible that these effects are exacerbated in adolescents with attention problems.

The results of the current study demonstrate that the consideration of adolescent attention problems within the context of type 1 diabetes is important to consider in clinical practice as they have implications for disease management. First, assessing attentional functioning shortly after diagnosis could help to flag youth early who may

struggle with the complex tasks in the diabetes regimen. Additionally, evaluating attention problems may also alert physicians and families alike that additional parental support with diabetes management is needed. Therefore, ongoing psychological treatment of attention problems and increased parental involvement with diabetes could preclude or correct detriments in adolescent diabetes adherence. In summary, the intersection of attention problems and type 1 diabetes management represents an important area for future study, with many implications for intervention with youth and their families.

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