Predictors of Metabolic Control among Adolescents with Diabetes: A 4-Year Longitudinal Study*

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Objective To employ a risk and resistance framework to examine changes in metabolic control over early to middle adolescence. Methods We interviewed 70 girls and 62 boys (mean age 12 years) annually for 4 years. Risk and resistance factors, including demographics, disease-related variables, self-care behavior, and psychosocial variables were assessed. Hemoglobin A1c was obtained from medical records. Results Multilevel modeling showed metabolic control deteriorated with age. Self-care behavior interacted with age to predict the decline, such that self-care was more strongly related to poor metabolic control for older adolescents. Eating disturbances, depression, and peer relations were related to poor metabolic control, whereas good family relations were related to better metabolic control for girls. Conclusions Independent risk factors for poor metabolic control included poor self-care, disturbed eating behavior, depression, and peer relations; parental support was an independent resistance factor for girls. Future research should examine mechanisms by which these relations emerge.

Key words adolescence; diabetes; metabolic control.

Effective management of diabetes, meaning keeping one’s level of blood glucose as close as possible to that of a healthy person, has important short- and long-term health consequences. Short-term consequences of poor glucose control include increased thirst and frequent urination when blood glucose levels are high and dizziness, sweating, and confusion when blood glucose levels are low (American Diabetes Association, 2008). Long-term consequences of poor glucose control include retinopathy, renal disease, and circulatory problems (Centers for Disease Control and Prevention, 2005).

Maintaining good blood glucose control during adolescence can be difficult. Metabolic control often deteriorates during adolescence (Greening, Stoppelbein, Konishi, Jordan, & Moll, 2007; Leonard, Jang, Savik, & Plumbo, 2003), posing risks for future health problems. On average, adolescents have worse metabolic control than both younger children and adults (Anderson, Ho, Brackett, Finkelstein, & Laffel, 1997). Part of the deterioration in metabolic control during adolescence has been attributed to the difficulty in keeping up with increasing insulin requirements caused by hormonal changes associated with puberty (Goran & Gower, 2001; Moran et al., 1999), and part has been attributed to a decline in self-care behavior. Adolescents on average do not follow physician’s recommendations for self-care as well as younger children and adults (Delamater, 2000a; Greening et al., 2007; Holmes et al., 2006).

The overall goal of the present article is to examine the decline in metabolic control over the transition from early to middle adolescence and to use the risk and resistance framework (Wallander, Varni, Babani, Banis, & Wilcox, 1989) to understand what factors might play a role in this decline. The risk and resistance framework is an expansion of the stress and coping model, and has been used to understand how children adapt to chronic physical disorders (Wallander & Varni, 1992, 1998). Chronic physical disorders, such as diabetes, are conceptualized as an ongoing strain. Risk factors impede adjustment, whereas resistance factors facilitate adjustment. Risk factors include characteristics of the disease and stressful life events, whereas resistance factors include both intrapersonal

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factors such as personality and interpersonal factors such as social support.

Although the framework is typically applied to the understanding of adjustment to disease, here we apply the model to understanding the influences on metabolic control. In addition to examining demographic factors (e.g., age and sex) and disease characteristics (e.g., insulin delivery method and years with diabetes), we examine a set of interpersonal risk or resistance factors, specifically self-care behavior, depressive symptoms, disturbed eating behavior, and a personality trait, unmitigated communion. We also examine a set of interpersonal resistance factors, specifically relationships with parents and peers. Many of these variables can be understood as either risk or resistance factors for metabolic control, depending on how they are conceptualized. For example, the presence of parental support can be conceptualized as a resistance factor by providing resources that would enable one to cope better with the demands of the disease, whereas the absence of parental support can be conceptualized as a risk factor for poor outcomes because those resources are lacking. Good self-care behavior can be conceptualized as a resistance factor for the deterioration in metabolic control that might be expected due to hormonal fluctuations; however, poor self-care behavior can be considered a risk factor for poor metabolic control. The risk and resistance variables that we examine are ones that are especially relevant to early and middle adolescence. Here, we briefly review the evidence for the risk and resistance factors that we examine in this article.

Poor self-care behavior would seem to be the obvious explanatory variable for the decline in metabolic control, as adolescents with diabetes are more likely to have problems with self-care behavior than adults and younger children (Delameter, 2000a). Problems with self-care begin to emerge between the ages of 13 and 15 years (Glasgow et al., 1999). Although the relation of self-care to metabolic control has been somewhat inconsistent (see Delameter, 2000b; Wysocki, Greco, & Buckloh, 2003, for reviews), two recent studies found relations of self-care behavior to metabolic control. One used the 24-hr recall measure to examine self-care and found that the frequency of testing and eating meals was associated with better control (Holmes et al., 2006), whereas the other found a sizeable relation between a global self-care behavior index and good metabolic control (Lewin et al., 2006). More longitudinal studies of self-care behavior and metabolic control would help to clarify this relation.

One risk factor that is related to poor self-care behavior and has been implicated in metabolic control problems among adolescents is eating behavior. Adolescents with diabetes are at increased risk for eating disorders and disturbed eating behavior because the diabetes regimen sets in motion a pattern of dietary restraint (Marcus & Wing, 1990), and because intensive insulin therapy has been associated with weight gain (Diabetes Control and Complications Trial Research Group, 1988). Adolescents with diabetes may purposely skip insulin injections or reduce their levels of insulin to lose weight (Rubin & Peyrot, 1992). Eating disorders and disturbed eating behavior have been associated with poor metabolic control among those with diabetes (Jones, Lawson, Daneman, Olmstead, & Rodin, 2000; Pollock, Kovacs, & Charron-Prochownik, 1995). It is during early adolescence that disturbed eating behavior is most likely to appear, which may account for part of the decline in metabolic control. Longitudinal studies that span the transition from early to middle adolescence can examine whether disturbed eating behavior has implications for metabolic control during this critical period of development.

Another risk factor for the decline in metabolic control over the course of adolescence is an increase in psychological distress. Two reviews of the literature concluded that diabetes is associated with some psychosocial difficulties during childhood and adolescence (Delameter, 2000b; Wysocki et al., 2003). A recent study concluded that children and adolescents with type 1 diabetes have nearly double the rate of depression of youth in general (Hood et al., 2006). The authors attributed the high rate of depression found in their study to the intensification of insulin management that has occurred over the past 10–15 years.

Indicators of psychological distress, in particular depression, have been linked to metabolic control among adults (Lustman, Freeland, Griffith, & Clouse, 2000), but the relation of depression to metabolic control among children is less clear. Two narrative reviews of the literature reached different conclusions, one suggesting that depression is related to poor metabolic control among adolescents with a few exceptions (Grey, Whittemore, & Tamborlane, 2002) and one concluding that relations are unclear (Dantzer, Swendsen, Maurice-Tison, & Salamon, 2003). To make matters more complicated, there are a few studies of children that have linked psychological distress to better metabolic control (Fonagy, Moran, Lindsay, Kurtz, & Brown, 1987; Weissberg-Benchell & Glasgow, 1997). Good metabolic control may be associated with some psychological costs for adolescents. For example, the intensive insulin treatment that improves physical health among adolescents with diabetes has been associated with greater distress (Madsen, Roisman, & Collins, 2002). More research is needed in this area to clarify the relation of
depression to metabolic control and to determine if that relation changes over the course of adolescence. Because depression increases in early adolescence (at least for girls; Nolen-Hoeksema, 2004), it is particularly important to determine if the implications of depression for metabolic control change over the course of adolescence.

To the extent that depression is associated with poor metabolic control, the relation may be direct or indirect. Depressive symptoms may have direct effects on metabolic control via counter regulatory hormones. Alternatively, depression may indirectly affect metabolic control by detracting from self-care behavior. Depression has been associated with poor self-care behavior among children (Kovacs, Goldston, Obrosky, & Iyengar, 1992). By measuring both depression and self-care behavior, we can examine this possibility.

Finally, a last risk factor that we examine is the extent to which a personality trait, unmitigated communion, is associated with metabolic control. Unmitigated communion is defined as a focus on others to the exclusion of the self (Helgeson & Fritz, 1998). Individuals who score high on unmitigated communion become overly involved in others’ problems at the expense of taking care of themselves. Unmitigated communion is a gender-related trait, meaning that females typically score higher than males (Helgeson & Fritz, 1999). Unmitigated communion has been associated with self-neglect and poor health behavior among college students and adults (Fritz & Helgeson, 1998). In one study of adolescents with diabetes, unmitigated communion was related to depressive symptoms, accounted for the sex difference in depressive symptoms, was related to poor metabolic control and predicted a decline in metabolic control over a 4-month period (Helgeson & Fritz, 1996). The relations of unmitigated communion to poor health outcomes also were stronger for older than younger adolescents. Because adolescence is a time of gender intensification (i.e., when gender norms become salient to adolescents; Hill & Lynch, 1983), it is during adolescence that unmitigated communion may begin to emerge and begin to be linked to poor health outcomes. Given that only one study has examined the implications of unmitigated communion for metabolic control among adolescents, additional research is needed to replicate this relation.

Turning to resistance factors, the social environment, in particular the family, has been implicated in metabolic control. Two reviews of the literature on social support show that most research focuses on support from the family and that family support is related to better adherence and better metabolic control (see Burroughs, Harris, Ponious, & Santiago, 1997; Ryan, 2003, for reviews). Support from families may enable adolescents to take better care of themselves, resulting in better metabolic control. An overall supportive family environment (i.e., families characterized by high cohesion, good communication, and low conflict) is associated with better metabolic control (Naar-King, Podolski, Ellis, Frey, & Templin, 2006), as is diabetes-specific support from families (Lewin et al., 2006; McKelvey et al., 1993; Schafer, McCaul, & Glasgow, 1986). Few studies examine the implications of both general and diabetes-specific support for metabolic control. We will do so in the present study.

As children transition into adolescence, another important source of support is peers (Wysocki & Greco, 2006). Peer relationships have not been investigated to the extent that family relationships have. During adolescence teens spend an increasing amount of time with peers (Larson & Verma, 1999), and parent support declines while friend support increases (Scholte, van Lieshout, & van Aken, 2001). In Wallander and Varni’s (1992) research on children with chronic physical disorders, social support from peers played a larger role than social support from parents in facilitating children’s adjustment. They suggested that this was due to a greater variability in peer support than parental support. In a study of children and adolescents with type 1 diabetes, both family and peer support predicted adjustment to diabetes among children, but only peer support predicted adjustment among adolescents (Varni, Babini, Wallander, Roe, & Frasier, 1989).

In the area of diabetes, studies that examine peer relations are more likely to focus on adherence rather than metabolic control. The relations of friend support to adherence are contradictory. Two studies showed that family support was related to adherence, but friend support was not (Shroff Pendley et al., 2002; La Greca, Swales, Klemp, Madigan, & Skyler, 1995), whereas another study showed that both family and friend support were related to better adherence (Skinner & Hampson, 1998). A fairly recent study of adolescents showed that both family relationships and peer support were associated with better illness management (Naar-King et al., 2006). Two studies showed that friend support was related to specific aspects of self-care, more frequent blood glucose testing in one study (Bearman & La Greca, 2002) and better dietary self-care over 6 months in another study (Skinner, John, & Hampson, 2000). Research on children and adolescents with diabetes needs to consider the implications of relationships with both family and friends for metabolic control as well as adherence and to determine whether the findings change over the course of adolescence.
It also is possible that increased involvement in peer relationships during adolescence plays a role in the decline in self-care behavior (Jacobson et al., 1990). Peers can have a negative impact on self-care to the extent that adolescents find that self-care behavior sets them apart from friends at a time when fitting in with friends is important. Peer pressure increases during early adolescence and peaks at around age 14 (Berndt, 1979). When faced with the choice between appropriate self-care behavior and peer desires, Thomas, Peterson, and Goldstein (1997) found that older adolescents had better problem solving skills than younger adolescents but were more vulnerable to nonadherence in the face of peer pressure. Research has rarely included both the positive and negative aspects of friend relationships when studying diabetes outcomes. The present study will address this gap.

**The Present Study**

In the present study, we examine changes in metabolic control over a 4-year period during adolescence. We focus on adolescence because it is a high risk period in terms of poor self-care behavior and poor metabolic control. It also is a time when relationships with parents and peers are in a state of flux. We predict a decline in metabolic control with age, and examine whether demographic and disease characteristics are associated with this decline. Consistent with the risk and resistance model (Wallander & Varni, 1992), we predict that psychosocial risk and resistance factors will predict metabolic control above and beyond demographic and disease variables. First, we predict that poor self-care behavior will be associated with this age-related decline. Second, we predict that disturbed eating behavior, depressive symptoms, and unmitigated communion are associated with a decline in metabolic control. Third, in contrast, we predict that good relations with family and peers will be protective against the age-related decline. With respect to family relations, we examine whether general family support or diabetes-specific family support has stronger implications for metabolic control. With respect to friend relations, we examine whether friend support is a resistance factor or negative relations with friends is a risk factor for metabolic control. Because self-care behavior could underlie each of the relations of these risk and resistance factors to poor metabolic control, we examine whether self-care behavior mediates the relation between any of the significant risk and resistance factors to metabolic control.

The longitudinal design we used allowed us to examine both cross-sectional (concurrent) and longitudinal (lagged) relations of risk and resistance factors to metabolic control. Cross-sectional analyses reveal whether two variables are simultaneously related across the multiple waves of assessment; they do not reveal anything about the causal direction of that relation. Longitudinal analyses go a step further in addressing causality by revealing whether the risk/resistance factor is associated with changes in metabolic control across each of the lags (e.g., year 1–2; year 2–3). For example, a concurrent negative relation between self-care and metabolic control would show that as metabolic control deteriorates, so does self-care across the period of adolescence examined. A longitudinal or lagged relation between self-care and metabolic control would show that self-care at 1 year predicts the change in metabolic control that occurs over the course of the next year for each of the lags.

This study expands on previous research in four ways. First, a major strength of this study is its longitudinal design. We examine whether self-care behavior and other risk and resistance variables are associated with metabolic control at each of the 4 years of assessment (cross-sectional) as well as whether these factors predict changes in metabolic control over the 4 years (longitudinal). Second, because we have a relatively large sample size, we can examine whether the relations of risk and resistance variables to metabolic control depend on age, as some studies have shown age-dependent relations. For example, Lewin et al. (2006) found that the links of problematic family relations to poor metabolic control were stronger among older teens, and Helgeson and Fritz (1996) found that unmitigated communion was associated with poor metabolic control only among older adolescents. Whereas previous studies often have included samples with wide-age ranges spanning childhood and adolescence, we have a relatively homogeneous age group of early adolescents that we follow for 4 years, enabling us to examine the 11–17 age spectrum. Third, we examine whether relations of psychosocial variables to metabolic control depend on the gender of the adolescent. A review article on children and chronic illness concluded that researchers have failed to incorporate gender into their models (Miller & La Greca, 2005). Gender is especially relevant to this research, as several studies have found that girls have worse metabolic control than boys during adolescence (Daneman, Wolfson, Becker, & Drash, 1981; La Greca et al., 1995; Lemmark, Persson, Fisher, & Rydelius, 1999; Pound, Sturrock, & Jeffcoate, 1996). Because depressive symptoms and disturbed eating behavior increase more so among girls than boys during adolescence, these risk factors might be more strongly linked to the decline in metabolic control among girls. Finally, we examine both intrapersonal and interpersonal risk and resistance factors, making distinctions that are often overlooked in the literature. We distinguish
between general and diabetes-specific parent support, we distinguish between support from family and support from friends, and we distinguish between the positive and negative features of peer relationships.

Methods
Participants
Adolescents were eligible to participate in the study if they were in the 5th, 6th, or 7th grade, were attending Children’s Hospital, had been diagnosed with diabetes for >1 year; and did not have another major chronic illness (e.g., cancer and rheumatoid arthritis). We had 132 adolescents with diabetes (70 girls, 62 boys) participating in the study. Age at study start ranged from 10.73 to 14.21, with a mean of 12.10. The majority of children (80%) were ages 11 and 12. Males and females were of a similar age. Length of illness ranged from 1 to 13 years (M = 4.91, SD = 2.96). The percentage of children using an insulin pump was 26% at study start and increased over each of the next 3 years (35%, 44%, and 50%); the rest of the children were using injections. The majority of participants were white (93%), 2% were African American, 1% was Asian, 1% was American Indian, and 3% were mixed races. These figures are consistent with the diabetes population seen at Children’s Hospital (8% minority), which draws from a largely suburban and partly rural area. The four-factor Hollingshead index (1975) of social status (mother and father’s education and occupation) revealed an average family score of 41.97 (SD = 11.05), which reflects the lower end of technical workers, medium business, and minor professionals.

Procedure
The study was approved by the appropriate Institutional Review Boards. Letters of invitation were sent to all adolescents with diabetes who were ∼11–13 years of age and attending Children’s Hospital (n = 307). Families could return a postcard indicating that they did not want to be contacted by phone about the study. Twenty families returned these postcards, refusing contact about the study without us being able to determine eligibility. We were able to reach 261 of the remaining 287 families by phone and determined that 90 were not eligible. Of the 171 eligible families, 39 refused and 132 agreed. Thus, our effective response rate was 77%.

For families who agreed, we set up an appointment immediately before or after the next clinic visit. Interviews were conducted in the General Clinical Research Center, which is separate from and not associated with the diabetes clinic. Parent consent and child assent were obtained at that time. Interviews with children were conducted aloud, with the exception of the depression scale and the eating disturbance items, which were completed by the child in private due to their sensitive nature. Research assistants unaffiliated with Children’s Hospital conducted these interviews. Children were provided with response cards (i.e., 1 = not at all; 2 = a little; 3 = a lot) for standardized instruments. While the child was interviewed, the parent most directly involved in diabetes care completed a questionnaire. Children were paid for their participation.

One year later (Time 2 [T2]), we interviewed 127 of the 132 (96%) children. Two years later (Time 3 [T3]), we interviewed 126 (95%) of the children, and three years later (Time 4 [T4]), we interviewed 127 (96%) of the children. The majority of parents completed questionnaires at T2 (94%), T3 (90%), and T4 (89%). The parent was the mother in 92% of cases.

Instruments
Unless noted, all of these instruments were administered to children. Means and SDs for all instruments at baseline are shown in Table I. Internal consistencies for each assessment period also are shown in Table I. The intercorrelations among the variables at baseline are shown in Table II.

Demographic Variables
Parents provided demographic information, including age, age at diagnosis, race, household structure, parent education, and parent occupation on the T1 parent questionnaire. From education and occupation information, we computed the four-factor Hollingshead index to measure social status (Hollingshead, 1975). We calculated body mass index (BMI) from height and weight measured at the clinic.

Pubertal Status
At each wave of assessment, parents completed the parent version of Carukdon and Acebo’s (1993) self-report of pubertal status. The authors showed that parent ratings were strongly correlated with child and pediatrician ratings of Tanner stages. When parents did not complete the questionnaire, we used the physician rating of Tanner stage. At T1, physician ratings were highly correlated with parent report, Spearman’s rho = .71, p < .001.

Metabolic Control
Metabolic control was measured with hemoglobin A1C (HbA1C) obtained at the clinic appointment measured by HPLC (Tosoh Instruments, San Francisco, CA) with normal range of 4.6–6.1%. HbA1C values indicate the average blood glucose level over the past 1–2 months. The average HbA1C at T1 for our sample was 8.04 (SD = 1.31). Current HbA1C recommendations for 13- to
19-year-old adolescents are below 8% (American Diabetes Association, 2006).

Self-care Behavior
We measured self-care behavior with the 14-item Self-Care Inventory (La Greca, Swales, Klemp, & Madigan, 1988). This instrument asks respondents to indicate how well they followed their physician’s recommendations for glucose testing, insulin administration, diet, exercise, and other diabetes-related behaviors. Each item is rated on a 1 (never do it) to 5 (always do this as recommended) scale. This scale reflects domains of self-care that have been regarded as important by the American Diabetes Association, and it has been associated with metabolic control among adolescents in a number of studies (Delamater, Applegate, Eidson, & Nemery, 1998; La Greca, Follansbee, & Skyler, 1990). We updated this scale by adding eight more contemporary items: three negative behaviors from Weissberg-Benchell et al. (1995): made up blood tests results because numbers were too high, made up blood test results because did not really test, took extra insulin because ate inappropriate food); three negative behaviors of our own (skipping meals, skipping injections, and eating foods that should be avoided); and two positive behaviors (rotating injection sites; measuring food). The positive behaviors used the above-mentioned scale; the negative items were scored on a similar scale ranging from 1 (never do it) to 5 (very often). We reverse scored negative items, summed across items, and took the average. Our revised measure was correlated .94 with La Greca’s original 14-item scale.

Disturbed Eating Behavior
The Eating Disorder Inventory (Garner, 1990) is a self-report instrument that was designed to identify the presence of various attitudes and behaviors that are associated with eating disorders. It is one of the most widely used self-report instruments, and its validity and reliability are well-established. It also has been widely used among adolescents with diabetes and shown to be valid (Grylli, Hafferl-Gattermayer, Wagner, Schober, & Karwautz, 2005; Jones et al., 2000; Steel, Young, Lloyd, & Macintyre, 1989). The two subscales that were used in the present study were drive for thinness (excessive concern with dieting, preoccupation with weight) and bulimia (episodes of uncontrollable eating or bingeing). Each item is rated on a five-point scale, ranging from 1 = never to 5 = very often. Three items from the drive for thinness scale were removed because they are biased by the presence of diabetes.

Steel et al. (1989) has shown that their inclusion has artificially inflated the presence of eating disturbances among people with diabetes.

Depressive Symptoms
We administered the abbreviated form of the Children’s Depression Inventory (CDI; Kovacs, 1985, 2001). The CDI is a self-report measure designed for children and adolescents. The abbreviated form consists of 10 items that are comprehensible at a first-grade reading level.

Unmitigated Communion
Unmitigated communion was assessed at baseline with Helgeson’s nine-item measure (1993; Fritz & Helgeson, 1998). Respondents indicated the extent to which they agreed or disagreed with each item on a five-point bipolar scale (sample items include “I always place the needs of others above my own,” “I can’t say no when someone asks me for help,” and “I often worry about other people’s problems”). Previous research has shown that this scale demonstrates acceptable internal consistency, ranging from .7 to .8, and high test–retest reliability (Fritz & Helgeson, 1998; Helgeson & Fritz, 1999), including a study of adolescents with diabetes (Helgeson & Fritz, 1996). This scale taps placing others’ needs before one’s own and distress over concern for others. The mean was 2.81, and the variable was normally distributed.
Table II. Correlations of Variables at Baseline

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<td>.19*</td>
<td>-.04</td>
<td>.41***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friend support</td>
<td>.15+</td>
<td>.46***</td>
<td>-.01</td>
<td>-.15+</td>
<td>.16+</td>
<td>.35***</td>
<td>.10</td>
<td>.11</td>
<td>.18*</td>
<td>.06</td>
<td>.10</td>
<td>.41***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friend conflict</td>
<td>-.03</td>
<td>-.05</td>
<td>.01</td>
<td>-.04</td>
<td>.07</td>
<td>.00</td>
<td>-.07</td>
<td>-.16+</td>
<td>.20*</td>
<td>.36***</td>
<td>.14</td>
<td>-.36***</td>
<td>-.12</td>
<td>-.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmitigated communion</td>
<td>-.01</td>
<td>.17+</td>
<td>-.05</td>
<td>-.08</td>
<td>.28***</td>
<td>.22*</td>
<td>-.00</td>
<td>-.02</td>
<td>.30***</td>
<td>.25***</td>
<td>.17+</td>
<td>-.01</td>
<td>.20*</td>
<td>.31***</td>
<td>.12</td>
<td></td>
</tr>
<tr>
<td>Metabolic control</td>
<td>.07</td>
<td>.01</td>
<td>-.19*</td>
<td>.03</td>
<td>.23***</td>
<td>.18*</td>
<td>-.34***</td>
<td>-.13</td>
<td>.12</td>
<td>.20*</td>
<td>.07</td>
<td>.01</td>
<td>.06</td>
<td>.16+</td>
<td>.17*</td>
<td>.29***</td>
</tr>
</tbody>
</table>

+ p < .10; *p < .05; **p < .01; ***p < .001.

Parent Relationship

We included a measure of general support provided by parents as well as diabetes-specific support provided by parents, so that we could distinguish between the two. To measure general support, we used Kerr and Stattin’s (2000) eight-item parent relationship measure to measure the quality of the relationship with the mother and quality of the relationship with the father. Participants rated the frequency of the same set of eight items for mother and for father on a scale from 1 (never) to 5 (very often). Items included “How often do you and your mom understand each other?” and “How often does your dad support and encourage you?” Because mother relationship quality and father relationship quality were highly intercorrelated at each wave of assessment (r’s ranged from .36 to .45), we averaged the two indices to form an overall parent relationship quality variable.

To measure diabetes-specific support, we selected six items from Schafer et al.’s (1986) Diabetes Family Behavior Checklist and two items from McKelvey et al.’s (1993) Diabetes Family Behavior Scale to develop a parent diabetes-specific support scale.

Friend Relationship

We administered the Berndt and Keefe (1995) friendship questionnaire. This instrument contains six scales: companionship, intimacy, instrumental support, self-esteem enhancement, conflict, and dominance. It has excellent reliability and validity. Because the positive aspects of friendship were highly intercorrelated at each wave of assessment, we standardized the four scales, summed them, and took the average to form an overall support index. The two negative aspects of friendship (conflict and dominance) were correlated at each assessment, but were unrelated to the positive aspects of friendship. Thus, we took the average of these two scales to form an overall negative relations index.

Overview of Statistical Analysis

We used multi-level modeling or longitudinal growth curve modeling to examine the relations of predictor variables to metabolic control (Singer & Willett, 2003). Multilevel modeling has numerous advantages over ordinary least squares (OLS) regression. First, with multilevel modeling, one is able to take advantage of all available data, including data from participants who did not complete all assessments. Second, multilevel modeling can be used when one expects variables to be correlated across time, a substantial improvement over OLS, which assumes that this autocorrelation is zero. Finally, and most importantly, multilevel modeling allows one to examine individual variability in rates of change. The rate of change is calculated for each individual, and then aggregated across individuals. We have a two-level model, such that wave of assessment or time (level 1) is nested within person (level 2). One can examine the relation of individual characteristics that change over time (time-varying predictors or level 1 variables such as pubertal status) as well as individual characteristics that do not change over time or are measured only once (level 2 variables such as sex) to our outcome, metabolic control, which changes with time. Our psychosocial predictor variables (e.g., friend support and
controlling for outcomes measured at \( T_n \). The lagged analyses take into consideration three lags: \( T_1 - T_2; T_2 - T_3; \) and \( T_3 - T_4 \). That is, we examine how a predictor variable, for example self-care, at \( T_n \) is related to metabolic control at \( T_{n+1} \) controlling for metabolic control at \( T_n \). We also examined the interactions of the predictor variables with the lag to determine whether longitudinal relations became stronger or weaker with time. For example, we examine whether the relation of self-care to changes in metabolic control is stronger at an earlier or later point in the study.

Given the importance of our outcome variable, metabolic control (operationalized as HbA1c), we report all relations that are significant at \( p < .05 \) as well as relations that are marginal at \( p < .10 \). However, we include only significant predictors in the simultaneous regression model and we only emphasize significant predictors in our discussion.

### Results

#### Cross-sectional Analyses

**Growth Parameter—Age**

As noted above, age was a significant predictor of metabolic control. The scattergram with the regression line is shown in Fig. 1. The relation was linear. A test of the quadratic function, which would suggest a curvilinear relation, was not significant.

**Demographic Variables**

Demographic and disease-related variables that are measured at each wave of assessment and change across assessments are referred to as level 1 variables or time-varying predictors. Both of the level 1 variables tested were associated with metabolic control: higher pubertal status was associated with higher HbA1c (\( B = .16, p < .05 \)), and insulin delivery method was associated with HbA1c (\( B = -.78, p < .001 \)), such that pump users had lower HbA1cs.

Demographic and disease-related variables measured at baseline are referred to as level 2 variables because they reflect individual difference variables associated with the person. We examined sex, social status, duration of diabetes, and BMI as level 2 variables. Among these variables, higher social status was associated with better metabolic control (\( B = -.03, p < .01 \)). Baseline BMI was associated with higher HbA1cs (\( B = .08, p < .001 \)), but this relation was moderated by age (\( B = .02, p < .05 \)): BMI was more strongly associated with higher HbA1cs for older than younger participants. (Findings were the same when we used the Center for Disease Control’s age-adjusted height and weight charts to compute percentiles.) Neither sex nor duration of diabetes was associated with metabolic control.
Thus, we controlled for three level 1 variables (age, pubertal status, and treatment delivery method), two level 2 variables (baseline social status and baseline BMI), and the interaction between age and BMI in cross-sectional multi-level models. We examined each psychosocial variable as an individual predictor of metabolic control, as well as whether it interacted with age or sex.

Self-care Behavior
Controlling for the previously mentioned variables, self-care behavior was associated with better metabolic control ($B = -.45, p < .001$), and interacted with age to predict metabolic control ($B = -.14, p < .05$). Poor self-care was more strongly associated with higher HbA1cs among older than younger adolescents. Self-care behavior did not interact with sex to predict metabolic control.

Risk and Resistance Variables
Bulimic symptoms marginally predicted worse metabolic control ($B = .17, p = .09$). Drive for thinness interacted with sex to predict metabolic control ($B = .32, p < .05$). Unexpectedly, drive for thinness predicted worse metabolic control for males but not for females. Neither variable interacted with age to predict metabolic control.

Depressive symptoms did not predict metabolic control nor did it interact with age or sex to predict metabolic control. Unmitigated communion revealed a trend toward poor metabolic control ($B = .16, p = .10$) but did not interact with age or sex.

Parent relationship quality interacted with sex to predict metabolic control ($B = .48, p < .05$), such that a good parent relationship was associated with better metabolic control for females only. Diabetes-specific support from parents did not predict metabolic control. Support from friends was associated with worse metabolic control ($B = .20, p < .05$), but negative friend relations was not. None of the social environment variables interacted with age to predict metabolic control.

Mediation
Because the interaction between self-care behavior and age predicted metabolic control, we could examine the extent to which self-care behavior explained or mediated the relations of the three significant psychosocial predictors to metabolic control: drive for thinness by sex interaction, friend support, and parent relationship by sex interaction. We entered the significant predictor variable into the equation followed by self-care behavior and the self-care behavior by age interaction. In each of the three cases, the predictor variable remained significant in the final equation with the $\beta$-coefficient only negligibly affected by the inclusion of self-care behavior. Also, in each case, the self-care behavior by age interaction remained significant. Thus, there was no evidence that self-care behavior mediated any of the relations of the psychosocial variables to metabolic control.

Final Model
To determine which risk and resistance variables independently predicted metabolic control, we entered the statistical control variables followed by self-care behavior and the three significant psychosocial predictors (friend support, drive for thinness by sex, and parent relationship by sex) into a single model to predict metabolic control. As shown in Table III, all three psychosocial predictors of metabolic control remained significant in the simultaneous regression equation as did the self-care by age interaction, suggesting that their relations were independent of one another.

Longitudinal Analyses
Demographic Variables
We examined the same background variables described above when predicting changes in metabolic control. Baseline BMI predicted changes in metabolic control ($B = .05, p < .001$), such that higher baseline BMI was associated with a greater increase in HbA1c over time. Age as a time-varying level 1 variable was not a significant predictor of changes in metabolic control. (This does not mean that age was not related to a decline in metabolic control, as shown in Fig. 1; it means age does not predict the size of the change between successive waves. That is, it is not the
case that older adolescents had a larger deterioration over the course of a year for each of the four years of the study. If we had followed adolescents for a longer time, we might expect older age to be associated with less of a decline in HbA1c. Social status was a marginal predictor of changes in metabolic control (B = −.14, p < .01). Depressive symptoms predicted increases in HbA1c over time (B = .49, p < .01). Friend negative relations also interacted with lag. Using the previously mentioned procedure, we found that friend negative relations was associated with an increase in HbA1c for the first lag (B = .49, p < .001) but that friend negative relations was not associated with changes in HbA1c for the second or third lag (B = .49, NS; B = −.30, NS). The parent relationship variables did not predict changes in HbA1c.

**Mediation**
Because self-care behavior was not a significant predictor of changes in metabolic control, we could not test mediation.

**Final Model**
To determine whether the significant risk and resistance predictors of changes in metabolic control were independent of each other, we conducted a final analysis in which the control variables were entered along with the four significant psychosocial predictors (bulimic symptoms, depressive symptoms, depressive symptoms × lag, and friend negative relations × lag). As shown in Table IV, bulimic symptoms, friend negative relations, and the interaction between friend negative relations and lag remained significant. Depressive symptoms and the interaction between depressive symptoms and lag became marginally significant, suggesting that some of its relation to the deterioration in metabolic control is accounted for by the other psychosocial variables. Note that lag is significant in the final model, reflecting the fact that HbA1c increased more between the first and second year of the study than among subsequent years.

**Table III. Final Cross-sectional Multilevel Model**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>Standard error</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.03</td>
<td>.26</td>
<td>.92</td>
</tr>
<tr>
<td>Pubertal status</td>
<td>.15</td>
<td>.08</td>
<td>.05</td>
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<tr>
<td>Method of delivery</td>
<td>−.69</td>
<td>.14</td>
<td>.000</td>
</tr>
<tr>
<td>Baseline BMI</td>
<td>.01</td>
<td>.03</td>
<td>.88</td>
</tr>
<tr>
<td>Baseline social status</td>
<td>−.02</td>
<td>.01</td>
<td>.06</td>
</tr>
<tr>
<td>Sex</td>
<td>−1.23</td>
<td>.56</td>
<td>.03</td>
</tr>
<tr>
<td>Baseline BMI × age</td>
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<td>.01</td>
<td>.08</td>
</tr>
<tr>
<td>Self-care behavior</td>
<td>−.14</td>
<td>.23</td>
<td>.55</td>
</tr>
<tr>
<td>Self-care behavior × age</td>
<td>−.13</td>
<td>.07</td>
<td>.04</td>
</tr>
<tr>
<td>Drive for thinness</td>
<td>−.06</td>
<td>.08</td>
<td>.43</td>
</tr>
<tr>
<td>Drive for thinness × sex</td>
<td>.32</td>
<td>.14</td>
<td>.02</td>
</tr>
<tr>
<td>Parent relationship</td>
<td>−.04</td>
<td>.15</td>
<td>.77</td>
</tr>
<tr>
<td>Parent relationship × sex</td>
<td>.52</td>
<td>.21</td>
<td>.01</td>
</tr>
<tr>
<td>Friend support</td>
<td>.26</td>
<td>.10</td>
<td>.01</td>
</tr>
</tbody>
</table>

(B = .49, p < .001). Friend negative relations also interacted with lag. Using the previously mentioned procedure, we found that friend negative relations was associated with an increase in HbA1c for the first lag (B = .49, p < .001) but that friend negative relations was not associated with changes in HbA1c for the second or third lag (B = .49, NS; B = −.30, NS). The parent relationship variables did not predict changes in HbA1c.
Discussion

We followed a fairly large group of teens over a 4-year period—a period of heightened risk with respect to self-care behavior and metabolic control. With little attrition over these 4 years, we were able to examine whether metabolic control deteriorated over time and whether self-care behavior and a set of other risk and resistance variables accounted for this deterioration. We found that age was related to a decline in metabolic control over the course of adolescence, as expected. Thus, our findings are consistent with a great deal of previous research documenting difficulties maintaining metabolic control during adolescence (Anderson et al., 1997). Our findings also show that the age-related decline is linear, meaning that the decline between age 11 and 12 years seems to be similar to the decline between age 15 and 16 years. Thus, the difficulties with metabolic control persist over a rather long timeframe.

Consistent with other research, we found that self-care behavior was related to good metabolic control over 4 years but relations were stronger among older adolescents. Perhaps the hormonal changes associated with puberty are more responsible for metabolic control difficulties during early adolescence, and self-care behavior is more responsible for metabolic control difficulties during later adolescence. Self-care behavior declined with age among these adolescents. Self-care behavior may decline as teens get older because parental monitoring, supervision, and involvement in diabetes care declines with age. Indeed, research has shown that parents become less involved in diabetes care as teens get older (Anderson et al., 1997; Holmes et al., 2006; Palmer et al., 2004; Skinner & Hampson, 1998). There also may be a methodological explanation for the interaction between age and self-care behavior; perhaps, older adolescents more accurately report their self-care behavior compared to younger adolescents.

A risk factor relevant to poor self-care behavior—disturbed eating behavior—also had implications for metabolic control. Cross-sectional analyses revealed a significant relation between drive for thinness and poor metabolic control. Unexpectedly, drive for thinness was more strongly related to poor metabolic control among boys than girls. Drive for thinness reflects a preoccupation with weight and weight gain. One reason that drive for thinness might have had a stronger relation to poor health for boys than girls is that it is more normative for girls to be preoccupied with their weight. Indeed, girls scored higher than boys on drive for thinness at all waves of assessment. Girls who score high on drive for thinness may reflect a group of relatively normal girls who have internalized societal norms to be thin as well as a problematic group of girls who have a more pathological concern with weight that translates into behavior with metabolic effects. Because a preoccupation with weight is less normative for boys, boys who voice these concerns may be engaging in behavior that has negative implications for metabolic control. Future research ought to investigate the nature of these behaviors in boys.

Interestingly, in the longitudinal analyses, it was bulimic symptoms—the more severe eating disturbance scale of the two—that predicted deterioration in metabolic control. Taken collectively, these findings are consistent with a wealth of data linking disturbed eating behavior to poor metabolic control (Jones et al., 2000; Pollock et al., 1995), and suggest that diabetes researchers should not overlook the possibility that boys could have a disturbed pattern of eating behavior that might have implications for their health.

We examined several other risk factors for metabolic control. Although depressive symptoms were not related to metabolic control in a concurrent fashion, we found that depressive symptoms predicted deterioration in metabolic control over time. This effect was limited to the earlier years of the study. Although some previous studies had noted that depressive symptoms were associated with better control, our finding is consistent with the majority of research showing that depressive symptoms are associated with metabolic control difficulties. Given the recent study showing a higher rate of depression among children with than without diabetes (Hood et al., 2006), health care professionals should be especially sensitive to the implications of mental health for the physical health of youth with diabetes.

We also examined whether a set of resistance factors related to the social environment were related to metabolic control. We found that both parental relations and peer relations had implications for metabolic control. A better relationship with parents was related to less of deterioration in metabolic control over time—but only for girls. The finding that parental relationships have a stronger impact

<table>
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<tr>
<th>Table IV. Final Longitudinal (Lagged) Multilevel Model</th>
<th>B</th>
<th>Standard error</th>
<th>p</th>
</tr>
</thead>
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<tr>
<td>Previous HbA1c</td>
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<td>0.04</td>
<td>.000</td>
</tr>
<tr>
<td>Lag</td>
<td>.30</td>
<td>0.12</td>
<td>.02</td>
</tr>
<tr>
<td>Baseline BMI</td>
<td>.04</td>
<td>0.02</td>
<td>.01</td>
</tr>
<tr>
<td>Depressive symptoms</td>
<td>.78</td>
<td>0.43</td>
<td>.07</td>
</tr>
<tr>
<td>Depressive symptoms × lag</td>
<td>−.37</td>
<td>0.31</td>
<td>.07</td>
</tr>
<tr>
<td>Bulimic symptoms</td>
<td>.27</td>
<td>0.11</td>
<td>.02</td>
</tr>
<tr>
<td>Friend negative relations</td>
<td>.35</td>
<td>0.14</td>
<td>.01</td>
</tr>
<tr>
<td>Friend negative relations × lag</td>
<td>−.37</td>
<td>0.12</td>
<td>.002</td>
</tr>
</tbody>
</table>
on the health of girls than boys is consistent with other research on adolescents that shows parental relationships are more strongly associated with the mental health of adolescent females than males (Leadbeater, Kuperminc, Blatt, & Hertzog, 1999; Murburg & Bru, 2004).

Peer relationships also seemed to play a role in metabolic control; however, they were more of a risk factor for poor control than a resistance factor protecting from the deterioration in metabolic control. In cross-sectional analyses, support from friends was associated with poor metabolic control. In the longitudinal analyses, negative relations with friends were associated with deterioration in metabolic control. This is one of the few studies to demonstrate an association between peer relationships and metabolic control. Taken collectively, these data suggest that relationships with friends may be a source of problems in regard to diabetes health. The concurrent relations between peer support and poor metabolic control suggest that adolescents who are more invested in or involved with friends may have metabolic control difficulties. Recall that the peer support measure was general in nature; a diabetes-specific one may have shown a different relation to metabolic control.

More attention should be paid to peer relationships and to identifying the ways in which those relationships might affect metabolic control. There are several possibilities. First, the turbulence of peer relationships during adolescence (Holmbeck, Friedman, Abad, & Jandasek, 2006) could be a source of distress that directly affects metabolic control. Second, relationships with peers (happy or unhappy ones) could simply detract from self-care behavior. Although we found no evidence that self-care behavior mediated the association of peer relationships to metabolic control, we did find that friend negative relations were related to poor self-care ($B = -.15, p < .001$). Thus, it seems to be the problematic aspects of relationships with friends that disrupt self-care behavior. Future research ought to investigate the mechanisms by which friends might influence self-care.

Although it theoretically made sense that disturbed eating behavior, problematic relations with friends and family, and depressive symptoms would be related to poor metabolic control by detracting from self-care behavior, we did not find evidence that self-care behavior explained any of these associations to metabolic control. One explanation for our inability to find mediation could be that we used a global measure of self-care behavior. The pathways by which each of these psychosocial variables might impact self-care could be more specific (i.e., problematic relations with friends might lead to less glucose testing). It also is the case that our measure of self-care behavior was a brief self-report instrument. More detailed and comprehensive measures exist. Their utility in future research could more definitively address whether the association of depression and family and friend relationships to metabolic control can be explained by self-care behavior.

The cross-sectional and longitudinal analyses revealed some similarities and some differences. Whereas self-care was a significant predictor in the cross-sectional analyses, it became marginal in the longitudinal analyses. Whereas bulimic symptoms were a marginal predictor in the cross-sectional analyses, it became significant in the longitudinal analyses. Parental support was significant in the cross-sectional analyses, whereas depressive symptoms were significant in the longitudinal analyses. There are several reasons for these divergent findings. First, the stability of the measure over time may contribute to some of the differences in the findings. For example, self-care changes over time; thus, it may be more predictive of metabolic control that is measured closer in time to self-care. One year may be too long of a lag. Bulimic symptoms, in contrast, might be more stable over this period of adolescence. Second, some psychosocial variables might have more immediate effects, whereas the effects of other variables take time to be realized. For example, the implications of depressive symptoms for metabolic control may not be immediate but may take some time to develop. The difference in the pattern of findings between the cross-sectional and longitudinal analyses have implications for understanding the mechanisms by which the psychosocial variables could exert their effects on metabolic control as well as understanding the directionality of those effects.

**Clinical Implications and Future Research Directions**

The findings that self-care behavior and metabolic control both decline with age, that self-care behavior predicts this decline, and that the relation of self-care behavior to metabolic control is stronger among older adolescents suggests that future researchers and health care professionals should pay more attention to the reasons for the decline in self-care behavior during adolescence. As previously suggested, one possibility is that parental involvement in diabetes care is declining with age. Researchers have suggested that clinicians should target increased parental involvement during adolescence (Wysocki et al., 2003), and several intervention studies have targeted parental involvement in diabetes care (Anderson, Brackett, Ho, & Laffel, 1999; Grey, Davidson, Boland, & Tamborlane, 2001). Communicating with families of younger
adolescents that family involvement in self-care is important throughout adolescence is important. Another possibility for the decline in self-care behavior is the increased involvement with peers. In this study, both the positive and negative aspects of friendship were associated with poor metabolic control. Future research should pay more attention to the implications that peers may have for self-care behavior.

Limitations and Conclusions
Before concluding, we must acknowledge several limitations of this study. First, we realize that we examined a large number of psychosocial variables. However, we justify this approach on three grounds. First, metabolic control is an extremely important outcome among those with diabetes. Second, metabolic control deteriorates during adolescence. Thus, anything that we can learn about what might contribute to that decline has substantial clinical significance. Third, despite the fact that we examined each of the psychosocial variable’s relations to metabolic control individually, we also conducted a simultaneous regression and limit our conclusions to the findings from those analyses. Our findings confirm the decline in metabolic control over adolescence using longitudinal data. We have confirmed previous findings regarding the role of disturbed eating behavior, self-care behavior, depressive symptoms, and family relations in metabolic control and highlight the importance of a new variable—peer relations. We also acknowledge the fact that we had a brief self-report measure of self-care behavior. Although better methods exist to measure self-care, they are more labor intensive. Our measure of diabetes-specific family support also is limited as we adapted a previous measure for this study. The fact that we found general parent support predicted metabolic control (although only for girls), but diabetes-specific support did not may be due to the fact that we used an adapted version of an existing measure. We also acknowledge the limited generalizability of the sample as the vast majority of participants were Caucasian.

In conclusion, we replicated the age-related decline in metabolic control over adolescence and showed that this decline persists over the early to middle adolescent years. As expected, we also found that self-care behavior plays an important role in this deterioration but noted that this role may be stronger among older adolescents. Also as expected, we found that eating disturbances were associated with poor metabolic control, and noted that on one occasion this relation was stronger among boys than girls, suggesting that future research ought not overlook boys when studying disturbed eating behavior among those with diabetes. We also added to the body of literature showing that depression has negative implications for metabolic control. As adolescence is a period marked by significant biological, cognitive, emotional, and social changes (Holmbeck et al., 2006), researchers should attend to the implications of negative affect and adjustment difficulties among those with diabetes for metabolic control. We also showed that both parent and peer relations had implications for metabolic control. Although theorists have long speculated that relationships with peers could affect metabolic control, this is one of the first studies to show that peer relations are associated with metabolic control. In this instance, the implications of peer relationships were negative. Future research should more closely examine the precise mechanisms by which these psychological and social environmental risk and resistance variables affect metabolic control.

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