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A Multivariate Model Exploring the Predictive Value of Demographic, Adolescent, and Family Factors on Glycemic Control in Adolescents with Type 1 Diabetes

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Abstract

Objective—The current study examined how a comprehensive set of variables from multiple domains, including at the adolescent and family level, were predictive of glycemic control in adolescents with Type 1 Diabetes (T1D).

Methods—Participants included 100 adolescents with T1D ages 10–16 years and their parents. Participants were enrolled in a longitudinal study about youth decision-making involvement in chronic illness management of which the baseline data were available for analysis. Bivariate associations with glycemic control (HbA1C) were tested. A hierarchical linear regression was implemented to inform the predictive model.

Results—In bivariate analyses, race, family structure, household income, insulin regimen, adolescent-reported adherence, cognitive development, adolescent responsibility for T1D management, and parent behavior during the illness management discussion were associated with HbA1c. In the multivariate model, the only significant predictors of HbA1c were race and insulin regimen, accounting for 17% of the variance. Caucasians had better glycemic control than other racial groups. Participants using pre-mixed insulin therapy and basal-bolus insulin had worse glycemic control than those on insulin pumps.

Conclusions—This study shows that despite associations of adolescent and family-level variables with glycemic control at the bivariate level, only race and insulin regimen are predictive of glycemic control in hierarchical multivariate analyses. Our findings are in line with more recent studies using complex statistical analyses. This model offers an alternative way to examine the relationship of demographic and psychosocial factors on glycemic control in adolescents with T1D.

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Keywords

Diabetes Mellitus; Type 1; Adolescent; Psychology

INTRODUCTION

Adolescence is a period of life in which the child begins to explore autonomy but is still reliant on family for financial, emotional, and psychological needs. Within the context of this complex and seemingly opposing set of priorities, for those adolescents who have a chronic illness such as Type 1 diabetes (T1D), self-management of their disease can be particularly challenging. Numerous studies have shown that both younger and older adolescents with T1D have poor glycemic control and health outcomes (1–3). In addition to being influenced by emerging comorbidities such as depression, early sexual activity, or drug and alcohol intake (4–7), adolescents' glycemic control may also be affected by underdeveloped and unregulated self-care behaviors which can lead to poor decision making and low adherence (8,9).

Previous research has shown that the development of adolescents' self-care behaviors is influenced by former and current family interactions and relationships in addition to parenting style and family communication which can influence adherence and glycemic control (10–13). Furthermore, decision-making ability can be learned from communication with key family members, and often this is the starting point from which adolescents begin to base their own decisions about their care (14–16).

There is longstanding literature that shows both cross-sectional and longitudinal associations of family and adolescent-level variables with glycemic control in both younger and older adolescents (13,17–19). Diabetes-specific family conflict, perceived parental burden, and critical parenting style have consistently shown associations with poor glycemic control (11,20,21). While more recent studies have confirmed these historical findings (10,22,23), some suggest that family and adolescent factors may not have as much of an impact on glycemic control as previously believed (11,24,25). Moreover, some newer studies using more complex modeling suggest that there is no association of family or adolescent factors with glycemic control in adolescents (26,27). The contradiction in the literature of whether or not family and adolescent factors play a prominent role in glycemic control remains unresolved.

There is inconsistency between studies of associations between adolescent and family-level variables and glycemic control at the bivariate and multivariate level. Hilliard et al. found that adolescent-level factors such as general emotional distress and diabetes-related distress, as well as family factors including diabetes-specific family conflict were associated with glycemic control at both the bivariate and multivariate level (20). Meanwhile, Vesco et al. found that the family factor of diabetes-related family conflict (DFRQ) was associated with glycemic control initially, however after controlling for confounders, only blood glucose monitoring (BGM) and insulin regimen remained predictive of glycemic control (24). Similarly, Holmes et al. found that while family and adolescent-level variables such as

family environment, child stress, and diabetes health control beliefs were predictive of glycemic control at the bivariate level, they did not remain so at the multivariate level (26).

Furthermore, some studies that have demonstrated a persistent association of adolescent or family-level variables with glycemic control at both the bivariate and multivariate levels have found a reduction in the strength of the association. Duke et al. found that adolescent report of critical parenting and parent report of adolescent adherence were associated with HbA1c; these factors accounted for 44% of the variance, but decreased to 25% after controlling for demographics and diabetes-specific variables (11). Butler et al. found that higher parental knowledge, lower adolescent negative affect, and lower parental perceived burden were associated with glycemic control with 25% of the variance in HbA1c explained by these factors, however after controlling for demographics and diabetes-specific variables, the variance accounted for 12% (25). Thus, it appears that demographic, disease-specific, and general diabetes stress measures have strong and consistent associations with glycemic control while developmental and psychosocial measures as they relate to the adolescent and the family have inconsistent and lesser associations with glycemic control.

The current study attempts to add to this body of work by examining how a comprehensive set of variables from multiple domains, including at the adolescent and family level, were associated with glycemic control in adolescents with T1D. More specifically, sets of variables that were examined were chosen based on prior research and included demographic and disease-specific characteristics (duration of illness, insulin regimen, and treatment adherence), adolescent-level variables (depressive symptoms, cognitive development, and psychosocial maturity), and family-level variables (coercive parenting, family communication, and adolescent-parent responsibility for T1D management). At the family level, we also included a novel validated scale, the Decision-Making Involvement Scale (DMIS), which measures how adolescents and their parents make decisions regarding chronic illness management and was associated with T1D adherence in prior research (17, 18). We hypothesized that each of the variables would show single associations with glycemic control and that while various adolescent and family-level variables would remain associated with glycemic control at the multivariate level, demographic and disease-specific variables would have the strongest association with glycemic control.

METHODS

The data presented here is a secondary analysis of baseline data from a longitudinal study currently under way, which examines how children and adolescents with T1D and their parents interact around illness management decisions.

Procedure

Youth and their parents were recruited from the Diabetes Center for Children at The Children’s Hospital of Philadelphia (CHOP) from October 2011 to June 2013. Youth were eligible if they were 8–16 years of age, had a diagnosis of T1D for at least one year, and were capable of completing questionnaires for at least 1 hour. They were excluded if they had a history of pervasive developmental disorder or intellectual disability, had a psychiatric hospitalization in the past year, had any illness besides T1D which required daily treatment

for greater than 6 of the 12 months prior to recruitment, did not live with or stay in contact with a biological or adoptive parent for at least 50% of the week, or if they and/or their parent did not speak English. Parents and youth were recruited as a dyad, with one parent and one youth per family eligible to participate.

One hundred sixty-seven families were contacted and assessed for eligibility. Of these families, 16 (9.6%) were deemed ineligible. Of the 151 eligible parent-youth dyads, 148 (98%) agreed to participate, but 10 (6.6%) could not be scheduled or reached again, 14 (9.3%) did not show up for their scheduled appointments, and 1 (0.7%) declined in person. Of the 123 (81%) dyads who consented and enrolled in the study, 4 (3.3%) did not fully complete Visit 1 and an additional 2 dyads (1.3%) were withdrawn by the PI after finding they did not meet eligibility criteria.

The final sample included 117 parent-youth dyads and did not differ from those that were eligible but not included (n=34) with regards to youth age, sex, race, ethnicity, or duration of illness. One hundred adolescents ages 10–16 years with T1D and their parents comprised the sample for the present analysis.

This study was approved by the institutional review board of CHOP and in accordance with the Declaration of Helsinki. Eligible families were assessed in conjunction with a regularly scheduled clinic appointment. Research personnel provided a thorough summary of the study to each parent-adolescent dyad and used developmentally appropriate language to ensure the adolescent's comprehension of the study procedures. After the parent gave permission and the adolescent gave assent, research personnel described the questionnaires and reviewed instructions. Questionnaires were independently completed by the adolescents. Each dyad was compensated $40for their time and effort.

Measurements

Demographic Questionnaire—Parents completed a demographic questionnaire, which characterized the adolescent, parent, and family. For the adolescents, data collected included gender, age, race, ethnicity, and date of T1D diagnosis; for parent and/or family, data collected included parent age, gender, race, ethnicity, highest level of education, current employment status, household income, current relationship status, highest level of education of spouse, current family structure, and how many children live in the home.

Glycemic Control—Members of the study team conducted medical chart reviews of the most recent clinic visit within 1 week of the research visit and abstracted glycated hemoglobin (HbA1c) values. Glycated hemoglobin values were either performed on the day of the clinic visit by point-of-care HbA1c tests or at a lab within two months before or after the visit. Eleven out of the 100 participants (11%) had HbA1c testing done on a different day than the most recent clinic visit with a range of 1 to 58 days from the visit.

Disease-specific Characteristics

Duration of Diabetes: Duration of diabetes was calculated as the time between the reported date of T1D diagnosis and the date of the most recent clinic visit.

Insulin Regimen: Insulin regimen was abstracted from the medical chart from the most recent clinic visit note, and was categorized as insulin pump therapy, basal-bolus insulin therapy, or pre-mixed insulin therapy (70/30 insulin).

Adherence to Diabetes Treatment: Adolescents and parents independently completed the Self Care Inventory (SCI), a well-established self-report measure of adherence in T1D that is appropriate for adolescents on both pre-mixed and flexible regimens (30–32). It contains 14 items assessing adherence to multiple aspects of the diabetes treatment regimen in the past month. We calculated a total score by averaging scores for the 14 items, with higher scores indicating better adherence. Cronbach's alpha was 0.69 for adolescent report and 0.70 for parent report in our sample.

Adolescent-level Variables

Depressive Symptoms: The short form of the Children's Depression Inventory (CDI;(33)) was utilized. It is a widely-used, reliable, and valid measure of depressive symptoms in children and adolescents.

Psychosocial Maturity: Adolescents completed the Impulse Control (IC) and Consideration of Others (COO) subscales of the Weinberger Adjustment Inventory (34,35) to assess psychosocial maturity. Cronbach's alpha was 0.74 for the COO and 0.77 for IC subscales in our sample.

Cognitive Development: Adolescents completed the Peabody Picture Vocabulary Test-IV (PPVT-IV), which is a measure of receptive language ability and a screen for verbal ability (36). This measure was chosen as a proxy for cognitive development due to its ease of administration and scoring by a trained research assistant. The raw score was used as the measure of cognitive development.

Family-level Variables

Decision Making Involvement Scale (DMIS): The DMIS was developed by the senior author and assesses the adolescent's involvement in discussions with their parents about decisions or problems related to illness management (28). Parent-adolescent dyads were asked to recall and describe a discussion related to a decision or problem they had about the management of T1D in the prior 2 weeks. Responses were paraphrased and recorded by the study personnel. The parent and adolescent then independently responded to the DMIS items that assessed specific parent and adolescent behaviors that might have occurred during the discussion. The questionnaire is comprised of 5 subscales, one of which, Parent Express, was of interest in the present analysis due to associations with worse adherence and lower likelihood of problem resolution in prior studies (29,37). The Parent Express subscale measures the extent to which the parent expressed an opinion or gave advice/information during the discussion. Internal consistency, test-retest reliability, and preliminary validity of the DMIS have been supported in prior research (17,18). Cronbach's alpha was 0.77 for adolescents and 0.86 for parent report in the present sample.

Diabetes Family Responsibility Questionnaire (DFRQ): The DFRQ is a 17-item scale, which assesses the extent that parents and youth take responsibility for various tasks related to diabetes management and was completed by adolescents and parents (38). Higher scores indicate more adolescent responsibility. The coefficient alpha was 0.78 for adolescents and 0.80 for parent report in the current study.

Parents as Social Context Questionnaire (PASCQ): Adolescent participants completed the 24-item PASCQ (39), which assesses how children perceive parenting style with respect to six dimensions: autonomy support, coercion, structure, chaos, warmth, and rejection. We utilized the Coercion subscale in the present analysis, with higher scores reflecting more coercion. Cronbach's alpha was 0.75.

Flexibility and Cohesion Evaluation Scales-IV (FACES-IV): Parents completed the FACES-IV (40), which is a 42-item self-report questionnaire that measures various domains of family functioning. This scale has been validated in prior work and has been shown to be significantly associated with measures of general family function and family satisfation (40). The 10-item subscale on communication was used for the present analysis. Higher scores indicate better communication. Cronbach's alpha was 0.87 in our sample.

Analysis Plan

Spearman's rho correlation was used to assess the association of continuous variables with glycemic control, and either t-test or ANOVA was used for the comparison of mean glycemic control by different categorical variables. Post-hoc tests were performed to assess for significant differences in glycemic control between the three insulin regimens given that the F value for the overall ANOVA was significant. Significant associations of variables with glycemic control at $p < 0.10$ in the bivariate analyses were considered for inclusion in predefined hierarchical linear regression models. These variables were grouped into 4 sets and considered for the hierarchical linear regression models in the following order (or steps): 1) demographic, 2) disease-specific (duration of diabetes, insulin regimen, adherence), 3) adolescent-level (depressive symptoms, cognitive development, psychosocial maturity), and 4) family-level (coercive parenting, family communication, and adolescent-parent responsibility for T1D management). Variables were retained from step to step if the test of the predictor was significant at $p< 0.10$ in the prior step. The reported results related to the final regression models were subjected to thorough examinations of the regression assumptions as well as model diagnoses, specifically multi-collinearity.

RESULTS

Participant Characteristics

Adolescent participants were, on average, 13 years of age (SD= 2.1). Roughly half of adolescent participants were female while the majority of parent participants were female. The majority of participants were Caucasian with a quarter of participants African-American. Thirty-nine percent of adolescent participants used insulin pump therapy, 41% were on basal-bolus insulin therapy, and 21% used pre-mixed insulin therapy (Table 1).

Bivariate Associations with Glycemic Control

Results of the bivariate analyses are displayed in Table 2. Regarding sociodemographic variables, adolescents who were Caucasian had better glycemic control compared to those who were not (8.5% (69 mmol/mol) vs. 9.6% (81 mmol/mol)). Participants in the two highest income groups had better glycemic control compared to other participants (8.3% (67 mmol/mol) vs. 9.1% (76 mmol/mol)), while those living in single parent households had worse glycemic control compared to those in two-parent households (9.5% (80 mmol/mol) vs. 8.7% (72 mmol/mol)). Regarding disease-specific characteristics, participants on insulin pump therapy had better glycemic control than those on either basal-bolus insulin or pre-mixed insulin therapy (8.3% (67 mmol/mol) vs. 9.1% (76 mmol/mol) or 9.4% (79 mmol/mol); p=0.0036). Duration of diabetes was not significantly associated with HbA1c. Adolescent-reported adherence was significantly associated with glycemic control while parent-reported adherence was not.

With regards to adolescent-level variables, more advanced cognitive development was associated with better glycemic control, while depressive symptoms, impulse control, and consideration of others were not significantly associated with HbA1c. With respect to family-level variables, parent and adolescent report of greater adolescent responsibility for management of T1D and parent and adolescent report of less parent expression of opinion/information during the dyadic discussion about T1D management were associated with better glycemic control. Coercive parenting style and family communication were not significantly associated with glycemic control.

Hierarchical Multiple Regression

Demographic variables that were significant at $p < .10$ in the bivariate analysis (race, household income, and family structure) were entered in the first step as Model 1. This model predicted glycemic control, with race as the only significant variable (Table 3). Race was retained for the second step, Model 2, in which disease-specific characteristics significant at $p<.10$ in the bivariate analyses (i.e., insulin regimen, adolescent report of adherence) were added. Race and insulin regimen remained significant predictors of glycemic control, but adherence did not. In the third step (Model 3), race and insulin regimen were retained and adolescent-level variables that were significant at $p < .10$ in the bivariate analysis (i.e., cognitive development) were added. Cognitive development did not improve model fit and was not significantly predictive of glycemic control. Lastly, in Model 4, race and insulin regimen were retained and family-level variables that were significant at $p < .10$ in the bivariate analysis (i.e., parent and adolescent report of responsibility for T1D management, adolescent and parent report of parent expression of opinion/information during T1D discussion) were added. The family-level variables did not improve model fit and none were significant predictors of glycemic control. Therefore, these variables were dropped, yielding a final model in which race and insulin regimen were the only significant predictors of glycemic control, accounting for 17% of the variance in HbA1c values. Relationships between the independent variables used in the regression analyses were examined and did not reveal any significant relationships.

DISCUSSION

The strengths of the current study include the use of a comprehensive set of variables in multiple domains, which have been previously shown to have associations with glycemic control, followed by hierarchical regression modeling to analyze the added impact of each successive set of variables on glycemic control. We hypothesized that demographics and disease-specific variables would have the greatest association with glycemic control but that various adolescent and family-level factors would remain predictive, albeit to a lesser degree. We found that while certain adolescent and family-level variables were associated with glycemic control in bivariate analyses, associations did not persist in multivariate analyses. The only significant predictors of glycemic control in multivariate analyses were race and insulin regimen, and these measures accounted for 17% of the variance in HbA1c. Our findings are in line with the results of more recent studies examining these variables using more complex modeling and analytic methods (23,26,27).

It is perplexing that the current body of work exploring the predictive value of adolescent and family-level variables on glycemic control in adolescents with T1D is somewhat contradictory. One explanation for why there may be mixed results in the literature is the use of different variables within each domain (adolescent or family) to examine associations of glycemic control. However, across studies that implement the same variable, there are still differences in findings (21,24). Another explanation could be that we continue to present a relatively simplistic portrayal of the relationships between adolescent and family-level variables and glycemic control. It is possible that more complex modeling between variables along with a priori hierarchical regression is necessary to see the full picture. Yet another explanation could be that the effect of the variables measured is different depending on the subset of the population studied. For example, when examining specific age groups within adolescence, Anderson et al. found that dyadic agreement of responsibility sharing was predictive of glycemic control when mean age was 10.6 years, but was not predictive in slightly older adolescents with a mean age of 13.5 years (21). The mean age in our study was 13 years of age, which is similar to the age of the older group in Anderson’s study, and could explain our negative findings. Regarding specific adolescent racial groups, Auslander et al. found that family resources and community stressors were worse in a population of African-American parent-adolescent dyads than Caucasians, and were independent predictors of glycemic control (41). It is unclear what the explanation for this phenomenon is, but there need to be more studies done to elucidate this issue.

The present findings should be interpreted in light of several limitations. First, the small sample size limited our ability to test more complicated relationships among the variables, including potential interaction effects. Second, all participants were recruited from one clinical center with certain educational practices and care patterns which may limit the generalizability of our findings. Third, this study was cross-sectional in nature, which makes it impossible to imply causal relationships. Despite this, the most recent studies examining such relationships longitudinally are consistent with our findings (28,29). Fourth, we did not take pubertal status into account, which has been shown in prior studies to negatively affect glycemic control independently of other variables and should be further explored (42). Lastly, we did not measure BGM frequency in the current study which could have

influenced our results as it has been found in previous studies to be associated with family factors, and also serves as an objective measure of adherence (22,25).

Since race remained a major predictor of glycemic control in our and other studies, it is possible that cultural norms and practices within racial groups as they relate to health and self-management of illness may be associated with self-care behaviors and glycemic control. Willi et al. recently found that black children with T1D had worse glycemic control than their Hispanic and white counterparts regardless of socioeconomic status and suggest that there may be modifiable parameters within specific racial groups that predict glycemic control (43). Nevertheless, there may be confounding of the association of race with glycemic control as prior studies suggest that measurements of glycated hemoglobin vary between Caucasians and African-Americans independently of direct glycemic measurements (44).

Given that certain adolescent and family attributes could be modified to improve glycemic control, it is important to explore this complex set of interrelated variables further. Reproducibility in the literature is vital as it would define whether adolescent and family attributes affect glycemic control as extensively as has been cited prior. The current study offers a different model as a way to examine this data, and if this method and our results were reproducible in larger multi-center studies it could help to resolve inconsistency of associations in the field. If there continue to be little or no associations of psychosocial and adolescent factors with glycemic control, it may be necessary to examine other domains of variables which are modifiable, such as health literacy or interactions of the patient with the health system, to better understand prediction of and targets for glycemic control. Further research should strive to improve reproducibility and explore other sets of variables that predict glycemic control to a greater degree.

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ABBREVIATIONS

T1D	Type 1 Diabetes
HbA1c	Glycated Hemoglobin
DMIS	Decision Making Involvement Scale
CF	Cystic Fibrosis
CHOP	Children's Hospital of Philadelphia
DSMP	Diabetes Self-Management Profile
CDI	Children's Depression Inventory

IC	Impulse Control
COO	Consideration of Others
PPVT IV	Peabody Picture Vocabulary Test, Version IV
DFRQ	Diabetes Family Responsibility Questionnaire
PASCQ	Parents as Social Context Questionnaire
FACES-IV	Flexibility and Cohesion Evaluation Scales, Version IV

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Table 1

Participant Characteristics.

Variable	n (%) or Mean (SD) (Range)
Adolescent age (years)	13 (2.1) (10–17)
Adolescent sex: Female	57 (57%)
Parent sex: Female	84 (84%)
Adolescent race	
Caucasian	61 (61%)
African-American	24 (24%)
Other	12 (12%)
Missing	3 (3%)
Illness duration (years)	5.9 (3.6) (1.1–14.7)
Insulin regimen	
CSII pump	39 (39%)
Basal-bolus	40 (40%)
Pre-mixed	21 (21%)
HbA1c (%)	8.8 (1.5) (6.4–13.6)
Adolescent-reported Adherence (C-SCI)	4.0 (0.4) (2.8–5.0)
Parent-reported Adherence (P-SCI)	4.0 (0.4) (2.9–5.0)

Note: NGSP/DCCT values are reported. To convert NGSP/DCCT values (%) to IFCC values (mmol/mol), use the following equation: NGSP = [0.09148 * IFCC] + 2.152).

Table 2

Bivariate Associations of Independent Variables with HbA1c.

Variable	r	t or F
Demographics		
Age	−.04	
Gender		.05
Race (Caucasian vs. others)		−3.79***
Household Income (≥$80,000 vs. <$80,000)		3.16***
Family structure (single vs. others)		2.06*
Disease Characteristics		
Duration of diabetes	.16	
Insulin regimen		5.97***
Adolescent-reported Adherence (C-SCI)	−.19*	
Parent-reported Adherence (P-SCI)	−.13	
Adolescent-level variables		
Depressive symptoms (CDI)	−.06	
Cognitive development score (PPVT)	−.24**	
Impulse control	.05	
Consideration of others	.03	
Family-level variables		
Coercive parenting style	.12	
Family communication	−.14	
Adolescent responsibility for T1D management (DFRQ; adolescent report)	−.18*	
Adolescent responsibility for T1D management (DFRQ; parent report)	−.20**	
Parent expression of opinion during T1D discussion (DMIS; adolescent report)	.22**	
Parent expression of opinion during T1D discussion (DMIS; parent report)	.30***	

Note: Coefficients using the above variables are based on Spearman's rho correlations, t-test, or ANOVA.

* p< .10,

** p <0.05,

*** p <0.01.

Table 3

Predictors of glycemic control in multiple regression analysis, by model.

	B Coefficient	SE_β	P value
Model 1: Demographics			
Adj. R^2=15%			
Caucasian race	**−0.73**	0.31	0.02
Household income	0.49	0.30	0.10
Single parent household	0.47	0.36	0.19
Model 2: Model 1 + Disease-specific characteristics			
Adj. R^2=17%			
Caucasian race	**−0.86**	0.30	0.006
Basal-bolus insulin therapy	**0.75**	0.31	0.02
Pre-mixed insulin therapy	**0.85**	0.40	0.04
Adolescent-reported Adherence (C-SCI)	−0.40	0.32	0.21
Model 3: Model 2 + Adolescent-level variables			
Adj. R^2=16%			
Caucasian race	**−0.75**	0.33	0.03
Basal-bolus insulin therapy	**0.78**	0.32	0.02
Pre-mixed insulin therapy	**0.87**	0.40	0.03
Cognitive development score (PPVT)	−0.006	0.007	0.40
Model 4: Model 3 + Family-level variables			
Adj. R^2=18%			
Caucasian race	**−0.85**	0.35	0.02
Basal-bolus insulin therapy	**0.86**	0.32	0.01
Pre-mixed insulin therapy	**0.73**	0.41	0.08
Adolescent responsibility for T1D management (DFRQ; adolescent report)	−0.58	0.68	0.40
Adolescent responsibility for T1D management (DFRQ; parent report)	0.62	0.86	0.47
Parent expression of opinion during T1D discussion (DMIS; adolescent report)	−0.02	0.22	0.93
Parent expression of opinion during T1D discussion (DMIS; parent report)	0.28	0.22	0.21
Final Model			
Adj. R^2=17%			
Caucasian Race	**−0.86**	0.30	0.006
Basal-Bolus insulin therapy	**0.75**	0.31	0.02
Pre-mixed insulin therapy	**0.85**	0.40	0.04

Note: For each step, non-significant findings were dropped from the model. Bold values indicate significance at $p < .10$.