Published in final edited form as:

J Adolesc Health. 2019 May ; 64(5): 622–630. doi:10.1016/j.jadohealth.2018.10.294.

The Role of Cognitive and Psychosocial Maturity in Type 1 Diabetes Management

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Abstract

Purpose: To explore the longitudinal relationship between treatment responsibility and type 1 diabetes (T1D) management (i.e., adherence and glycemic control) in adolescence, and examine whether indicators of cognitive and psychosocial maturity moderate the link between youth responsibility and diabetes outcomes.

Methods: Participants included 117 youth with T1D and their parents. Youth (ages 8-16 years) and parents were assessed five times over two years. Using a cohort sequential design, we estimated the growth trajectory of adherence and glycemic control (i.e., HbA1c) from age 8 to 18. Treatment responsibility, verbal ability and impulse control were used as predictors of within-person variability and between-person differences in the growth parameters (i.e., intercept and slope).

Results: Adherence and HbA1c declined linearly from ages 8-18. Significant within-person interactions between impulse control and responsibility revealed that on occasions when youth experienced increases in both responsibility and impulse control, adherence and HbA1c were higher than would be predicted by the age-related trajectory. For adherence only, when youth acquired more responsibility, without experiencing contemporaneous gains in impulse control, adherence worsened. For glycemic control only, a significant within-person interaction indicated that time-specific increases in both youth responsibility and verbal capacity was associated with a concurrent decline in HbA1c.

Conclusions: The present findings underscore that the associations between treatment responsibility and diabetes management depend on youths' maturational context. Intervention efforts to enhance impulse control skills in youth with diabetes may prevent the decline in diabetes management that tends to occur as youth acquire more responsibility for diabetes-related tasks.

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For adolescents, more so than for children and adults, diabetes management appears to be particularly challenging, as evidenced in studies showing that both adherence and glycemic control deteriorate during this developmental period.[1-3] One potential contributing factor to the decline in diabetes management during the transition to adolescence is that youth may begin to take more responsibility for diabetes tasks before they are ready to manage diabetes independently.[4-5] As youth transition into adolescence, parents may be inclined to transfer responsibility of diabetes care to their children for several reasons, including youths' need for greater autonomy, parents' belief in their adolescent's competence,[6] or belief that their child is sufficiently matured based on age or physical signs of pubertal development.[7-10] However, these broad developmental factors (e.g., age, puberty) are imperfect markers of maturity.[10] Furthermore, prior research has found that pubertal status did not influence the link between responsibility and diabetes outcomes, [11] suggesting that other developmental factors are at play.

Daily adherence may be difficult for adolescents, in part, because the demands of planning ahead and constant self-monitoring often clash with adolescents' inclination toward immediate rewards, especially in the presence of peers.[12] Given this developmental context, youth with diabetes need to be equipped with regulatory skills to resist temptation and maintain self-control when confronted with a variety of psychosocial influences in order to manage their illness.[13] Studies on the role of regulatory skills and diabetes management show that youth with higher self- or impulse control (e.g., ability to control inappropriate desires, emotions, or actions[14]) tend to engage in more self-care behaviors and have better glycemic control compared to youth with low impulse control.[15-17] Studies that assess regulatory ability more globally as 'executive functioning,' using measures that combine indices of both cognitive (including skills related to working memory and attention) and psychosocial (e.g., impulse control) skills, demonstrate that youth with better executive functioning are more adherent and have better glycemic control than youth with low executive function.[18-21] Though several researchers and clinicians advocate that adolescents' level of responsibility for diabetes care should be balanced with their level of maturity,[4,5] empirical research in this area remains sparse.

To our knowledge, only one prior study has examined the interplay among maturity, treatment responsibility, and diabetes management in youth. In that cross-sectional study, Wysocki and colleagues[22] found that youth with excessive levels of diabetes responsibility relative to their maturity (measured as a composite of intellectual, cognitive, and academic maturity) had lower adherence and worse glycemic control compared to youth with more congruent levels of responsibility and maturity. In other words, diabetes management was better when youth responsibility matched their level of maturity. Though relevant, this study's assessment of maturity did not assess regulatory or psychosocial ability, an important aspect of maturity that has been linked to diabetes management in youth.[17-21] Moreover, theoretical and empirical work show that cognitive skills mature earlier than psychosocial skills,[23,24] suggesting there may be a period during which adolescents may think or talk like adults but behave in more immature ways. It may be important to make the distinction between cognitive (e.g., intellectual) and psychosocial (e.g., impulse control) maturity because although mature decision-making is the product of both cognitive and psychosocial abilities, these aspects of development proceed along somewhat different timetables. This is relevant to consider because youth may begin to acquire more diabetes responsibility when they exhibit high levels intelligence, abstract thinking, or verbal ability, but the regulatory skills necessary to successfully execute diabetes-related tasks are not yet fully developed. Indeed, it is important to understand whether these different aspects of development have differential impact on how well youth perform with increasing diabetes responsibility.

The present longitudinal study examined associations between youth responsibility and diabetes outcomes (i.e., adherence and glycemic control) in the context of both cognitive and psychosocial maturity. We used measures of verbal ability and impulse control as proxies for cognitive and psychosocial maturity, respectively. We investigate if, and how, cognitive and psychosocial maturity *moderate* the relationship between treatment responsibility and diabetes outcomes. Using latent growth curve modeling, we estimated changes in adherence and HbA1c from ages 8 to 18 and examined whether changes in these outcomes were independently associated with youth responsibility, verbal ability, and impulse control. Lastly, we examined whether the associations between youth responsibility and diabetes outcomes depend on verbal ability and impulse control. We hypothesized that impulse control (but not verbal ability) would moderate the relationship between responsibility and diabetes outcomes. Specifically, we expected that increases in youth responsibility would be more detrimental to diabetes outcomes for youth with low impulse control, and for youth who experience small gains in impulse control over time. In contrast, we expected that more responsibility would be less— or not at all— detrimental for youth with high impulse control or who exhibit large gains in impulse control over time.

Methods

This study was a secondary analysis of data from a study designed to examine predictors and outcomes of decision making involvement in youth with chronic illness.[25] The study used a cohort sequential design, which involves the examination of different age cohorts over the same time period, and allows for the combination of multiple short-term longitudinal data points into a single long-term growth pattern using growth curve modeling.[26] Nine age cohorts (8-to-16 year-olds) were assessed at baseline and followed for two years, with assessments occurring every six months (for 5 total assessments). With only two years of data collection, the nine age cohorts were linked to form a common developmental trajectory spanning ages 8 to 18. The sample included children (ages 8-9) because we were interested in capturing changes in treatment responsibility during the transition to adolescence.

Participants and Procedures

Parents and youth were recruited from a large tertiary children's hospital between October 2011 and June 2013. Participants were eligible if they were English-speaking, the parent was the biological or adoptive guardian, and youth had been diagnosed with T1D for at least one year, and lived with the parent at least 50% of the week. Youth were ineligible if they had developmental delay, past-year psychiatric hospitalization, or another life-threatening medical condition, unrelated to T1D, which required daily treatment for more than 6 months in the last year. We identified potential participants from outpatient clinic lists and schedules, and sent parents a letter describing the study. We then contacted parents via telephone or in person (at clinic) and screened them for eligibility.

We identified and screened 167 families by telephone, among which 90% (n=151) were eligible for the study. Of those, 98% (n=148) agreed to participate in the study, but 7% (n=10) did not schedule a study visit, and 9% (n=14) did not show up to the study visit. One (1%) additional family declined in person at the initial study visit. The remaining 81% (n=123) of eligible dyads consented and enrolled in the study, but four families did not complete the baseline assessment, and two were withdrawn from the study because they no longer met eligibility criteria. The final sample was composed of 117 participant dyads.

Data were based on self-report questionnaires from youth and parents. Research personnel read questionnaires to youth ages 8-10 years to promote comprehension. In general, Visit 1, 3, and 5 assessments were conducted in person (whenever possible), while Visit 2 and 4 assessments could be completed either in person or over the phone. All study procedures were in accordance with U.S. guidelines for the ethical conduct of human subject research, and approved by the institutional review board.

Measures

Adherence.—At all visits, youth and parents completed the Self Care Inventory, [27] a 14-item measure to assess past-month adherence to multiple aspects of the diabetes treatment regimen (e.g., glucose testing, administering and adjusting insulin, eating regular snacks). Responses range from 1 (never do it) to 5 (always do this without fail). Higher scores indicate better adherence. Cronbach's alphas across all visits ranged from 0.70 to 0.81 for parent report, and 0.69 to 0.83 for youth report.

Chart Review.—During visits 1, 3, and 5, study staff completed a review of youth' medical charts to obtain information regarding insulin regimen (pump, premixed 70/30, or basal-bolus) and hemoglobin A1C (HbA1c, a measure of glycemic control).

Treatment Responsibility.—At all visits, youth and parents completed the Diabetes Family Responsibility Questionnaire, [28] a 17-item measure of responsibility in T1D care between youth and parents. Items included tasks such as adjusting insulin dose, rotating injection sites, remembering and administering insulin shots. For each task, a "1" indicated that the parent takes primary responsibility, a "2" that parent and youth share responsibility, and "3" that youth takes primary responsibility for the task. Higher scores indicate greater youth responsibility for diabetes care. Cronbach's alphas across all visits ranged from 0.82 to 0.86 for parent report, and 0.80 to 0.84 for youth report.

Verbal Ability.—During in-person visits 1, 3, and 5, youth completed the Peabody Picture Vocabulary Test, 4th Edition (PPVT-IV), which is a measure of verbal cognitive ability.[29] The PPVT-IV consists of 204 items, grouped into 17 sets of 12 items each. Each item consists of four-color illustrations, and the respondent must choose the picture that best represents the meaning of the word presented orally by the examiner. The PPVT-IV is designed to include items of increasing difficulty with age. Scores on the PPVT-IV are highly correlated with scores on the Wechsler Intelligence Scale for Children, 4th Edition

(WISC-III; .82-.91), and have been used as a proxy of cognitive functioning in pediatric samples.[30] We used the raw test score as a developmental indicator of cognitive ability.[31]

Impulse Control.—At all visits, youth completed the eight-item impulse control subscale from the Weinberger Adjustment Inventory.[32] Participants indicate how accurately a series of eight statements (e.g., "I say the first thing that comes into my mind without thinking enough about it;" "When I am doing something fun, I tend to get carried away and go too far") describes them on a 5-point Likert-type scale. Cronbach alphas across visits ranged from 0.76 to 0.84.

Covariates of interest in the present study included baseline adherence, youth sex (male: yes/no), age at baseline, minority status (yes/no), duration of T1D diagnosis, family income, whether parent was employed full-time (yes/no), family structure (single-parent household: yes/no), and insulin regimen (pump, premixed 70/30, or basal-bolus).

Data Analysis

We used latent growth curve modeling to estimate developmental patterns of adherence and HbA1c from ages 8 to 18. Growth curve modeling partitions the variance around a trajectory of change into within-person (Level 1) and between-person (Level 2) components. With a two-level model structure, we can use repeated measures of time-varying predictors to explain within-person variance, and time-invariant predictors to explain differences between-persons. All procedures described below were run separately for each outcome (i.e., adherence and HbA1c).

Models were run separately for each reporter (youth and parent), using age as the marker of time, centered at the grand mean (13.77 years). Unconditional growth curve models were first estimated to identify the best-fitting trajectory of change in the outcome. After finding the bestfitting unconditional growth curve, the intercept and slope were regressed on a number of demographic factors to estimate between-person effects. Covariates were first tested in separate models, and then all significant variables were tested simultaneously in a single model. Only variables that remained significant in the full model were included as controls in subsequent models.

Our main predictors (e.g., youth responsibility, verbal ability, and impulse control) were entered at Level 1 (within-person change) and Level 2 (between-person differences). At Level 1, values of each predictor were centered at participants' baseline score using a person-centering technique so that these variables represent deviation, or cumulative change, from the first time point.[5, 33] Only fixed effects of time-varying predictors were estimated. At Level 2, baseline values of each predictor, centered at the grand mean, were used to estimate between-person differences in the growth parameters (i.e., intercept and slope) of each outcome. To test moderation, interaction terms between responsibility and verbal ability, and responsibility and impulse control, were entered at Level 1 and Level 2.

Missing data were addressed using full Information Maximum Likelihood estimation in Mplus 7.1. With the exception of our measure of verbal capacity, data missing was low and range from 0 to <4.5% for each study visit. For verbal capacity, two youth had missing data at baseline; 20 youth had missing data at visit 3, and 28 had missing data at visit 5. These missing data were due to participants being unable to attend the visit in person, which is necessary for PPVT administration. Statistical tests indicated that youth with *vs*. without missing data on verbal ability did not differ with respect to baseline age, demographics, or main variables of interest. Data were assumed to be missing at random.

Results

Participants

Table 1 displays participant demographic data. Of the 117 dyads, 78 completed all follow-up visits, 33 completed between 1 and 3 follow-up visits, and 6 did not complete any follow-up visits. Overall, there were 117 evaluable cases at visit 1, 97 at visit 2, 101 at visit 3, 97 at visit 4, and 96 at visit 5. There were no significant differences between participants who completed no follow-ups, 1-3 follow-ups, and all 5 follow-ups with respect to baseline age, demographics, or main variables analyzed in the present study (all *p*s>0.05).

Trajectories of Adherence

Adherence declined linearly from ages 8 through 18, with an average decline rate of −0.05 (SE=0.02, p<0.01) and −0.06 (SE=0.01, p<0.001) according to youth and parent reports, respectively. There was significant variability in the growth parameters (intercept and slope), suggesting that participants differed in both their overall estimated levels of adherence, and the rate at which adherence declined.

Predictors of Youth-Reported Adherence.—Among the covariates tested, the only factors that remained significant in the full covariate model were baseline adherence, minority status, and income (Table 2, Model 2). Subsequent models adjusted for these covariates. As shown in Model 3 (Table 2), youth-reported responsibility was not a significant predictor of within-person variability in youth-reported adherence, suggesting that changes in responsibility were not associated with changes in adherence. However, at Level 2, youth-reported responsibility was a significant negative predictor of individual differences in the slope (b=−0.10, SE=0.04, p=0.019, Table 2, Model 3). Specifically, youth who reported higher baseline responsibility had a faster rate of decline in adherence from age 8 to 18, compared to youth with lower baseline levels of responsibility.

As shown in Table 2, Model 3, we found that impulse control was a significant positive predictor of within-person variability in youth-reported adherence (b=0.18, SE=0.04, p<0.001; Table 2, Model 3). This finding indicated that on occasions when youth experienced an increase in impulse control (relative to baseline), they also exhibited a concurrent increase in adherence. Verbal ability was not a significant predictor of within-person variability in youth-reported adherence. However, baseline verbal ability was a significant positive predictor of individual differences in the rate of decline in adherence (b=0.001, SE=0.001, p=0.049). Adherence declined more slowly in youth with higher baseline verbal ability.

To test whether the association between youth responsibility and adherence varied as a function of concomitant changes—and individual differences—in maturity, we tested interactions between responsibility and impulse control, as well as responsibility and verbal ability, at both Level 1 and Level 2. At Level 1, a significant interaction between youth-reported responsibility and impulse control (b=0.66, SE=0.13, p<0.001; Table 2, Model 4) indicated that when an increase in youth responsibility was accompanied with an increase in impulse control, there was a time-specific increase in adherence. When youth responsibility increased without concurrent increases in impulse control, there was a decline in youth-reported adherence (b=−0.30, SE=0.14, p=0.029). We found no evidence of moderation at Level 2, indicating that adherence declined faster in youth with more baseline responsibility regardless of differences in impulse control. Lastly, the interaction between youth responsibility and verbal ability was not significant at Levels 1 or 2 (Table 2, Model 5).

Predictors of Parent-Reported Adherence.—Parent-reported youth responsibility, impulse control, and verbal ability were not significantly associated with changes in parent-reported adherence, nor were their interactions (Table 3).

Trajectories of Glycemic Control

HbA1c increased linearly with age (b=0.13, SE=0.04, p<0.01; Table 4, Model 1). There was significant variance around the intercept but not the slope, indicating that youth varied in their overall levels of HbA1c but not in the way in which HbA1c changed over time. Given the lack of variance around the slope, we constrained the variance to 0 in subsequent models. Minority status and insulin regimen were significant covariates of HbA1c (Table 4, Model 2).

Impact of Predictors on HbA1c.—In models that included youth-reported responsibility, higher verbal ability at baseline was marginally associated with lower overall HbA1c (Table 4, Model 3). A significant interaction between youth-reported responsibility and impulse control (at Level 1 only) indicated that on occasions when youth experienced an increase in *both* responsibility and impulse control, there was a time-specific decline in HbA1c (b=−1.64, SE=0.60, p<0.01; Table 4, Model 4). Similar results were observed in the within-person interaction between youth-reported responsibility and verbal ability (b=−0.10, SE=0.04, p<0.05; Table 4, Model 5), such that HbA1c was lower on occasions when youth experienced an increase in *both* responsibility and verbal ability. To rule out the possibility that improvements in HbA1c that occurred when adolescents exhibited gains in verbal ability or impulse control were simply a consequence of youth being more adherent, we re-ran the HbA1c models to control for youth-reported adherence and the results did not change.

There was no evidence of moderation in the HbA1c models that included parent-reported responsibility as the predictor (Table 5).

Discussion

While a decline in T1D outcomes and an increase in youth responsibility for diabetes-related tasks are well-documented phenomena that co-occur during the transition to adolescence,[1, 4-5] the association between these two processes is inconsistent in the existing literature and may depend on developmental factors. In the present study, we explored the relationship between youth responsibility and diabetes management (i.e., adherence and HbA1c) from ages 8 to18, and examined whether their association depended on verbal ability and impulse control. With respect to youth-reported (but not parent-reported) adherence, we found that adherence declined more slowly in youth with high levels of verbal ability at baseline. At the within-person level, impulse control moderated the association between youth responsibility and adherence revealing that on occasions when youth experienced an increase in both responsibility (according to youth report) and impulse control, adherence was higher than would be predicted by the age-related trajectory. Put together, higher levels of verbal ability may slow down the rate of decline in adherence, but maturational gains in impulse control appear to be necessary to augment adherence among youth, especially during times when youth assume more responsibility for diabetes care. With respect to glycemic control, we found that both impulse control and verbal ability moderated the association between youth responsibility and HbA1c (at the within-person level), such that when youth experienced increases in diabetes responsibility in the context of maturational growth in impulse control and verbal fluency, there was a decline in HbA1c.

Our finding that impulse control moderated the longitudinal relation between youth responsibility and adherence is not entirely surprising. One possible interpretation for this finding is that daily adherence to a demanding treatment regimen requires the ability to control emotions and behaviors, independent of verbal abilities. This is important to consider in the context of T1D, because parents may consider giving more responsibility to their adolescent on the basis of that adolescent's ability to communicate and verbalize his needs), without considering impulse control skills, which may not be as readily apparent but are important for managing diabetes independently.[15-17]

The finding that specific aspects of both psychosocial and cognitive maturity moderated the longitudinal associations between youth responsibility and HbA1c suggests that increases in these aspects of development are necessary to help youth manage diabetes independently. It is possible that adolescents who experience increases in impulse control are better able to regulate themselves in such a way that having more responsibility for diabetes tasks does not feel overwhelming or evoke a stressful response that could, in turn, influence physiological processes. More difficult to interpret is the finding that a simultaneous increase in both youth responsibility and verbal ability was associated with better glycemic control. It is possible that increases in verbal ability enables youth to better understand and communicate with others about their illness. However, it is unclear why this would be associated with better glycemic control, but not adherence. Future work is needed to explore the process by which verbal ability may bolster glycemic control when youth acquire more responsibility for diabetes tasks.

Our results support the contention that associations between youth responsibility and diabetes outcomes depend on youths' maturational context.[2, 11] Though promising, the current findings should be interpreted with caution, as they were only observed in youth-reported data and were not corroborated by parent report. The discrepancy in youth vs. parent reports may suggest underlying conflict between adolescents and their parents regarding diabetes care. Indeed, it is not uncommon for parents and adolescents to disagree on issues related to diabetes management.[9-10] Adolescents and parents may use different criteria for evaluating whether or not a task was successfully completed and may have different perceptions of responsibility. Even in instances when adolescents have responsibility for a particular diabetes task, parents may checkin and monitor task completion and, as such, consider themselves somewhat responsible for the task. Future work is needed to disentangle the effects of direct parental involvement versus monitoring, and to understand how they interact with youth maturity to influence diabetes outcomes. The discrepant findings between youth and parent report could also be the result of social desirability or inaccurate recall in self-report data. To overcome the limitations of selfreport data, future work may benefit from the additional use of behaviorally oriented measures of diabetes responsibility and adherence, such as the 24-hr recall.[34]

An additional limitation of the present study is that we had a considerable amount of missing data on our measure of verbal ability, due to participants needing to complete visits over the phone (which did not allow for administration of the PPVT). Though we found no differences between individuals with vs. without data on this measure, our findings related to verbal ability warrant caution, as estimations of change in verbal ability may be underpowered.

Despite these limitations, the study had several methodological strengths. Among them was its longitudinal design, which allowed us to examine both between-person differences and within-person fluctuations in the change trajectory of adherence and HbA1c. We also contributed conceptually and methodologically to our understanding of the role of youth responsibility in the context of youth maturity. While prior work has focused on changes in self-efficacy and autonomy as factors that may speak to youth maturity, [9, 11] the present study focuses explicitly on the role of specific aspects of cognitive and psychosocial maturity. Our findings suggest that adolescents' impulse control may inform the most adaptive timing for transferring diabetes responsibility from parent to child.

From a practical standpoint, our findings support intervention efforts to enhance psychosocial skills in youth with diabetes.[35] Although all individuals with T1D may benefit from improvements in psychosocial skills, the present findings suggest that such interventions may be most beneficial as youth acquire increasingly more responsibility for diabetes care. Clinically, it might be helpful for providers to track how parents and youth distribute responsibility of diabetes tasks, and periodically assess youths' indicators of psychosocial maturity to ensure that decisions related to the transfer of responsibility are made in the context of changes in maturity. It is important for parents and providers to know that youth typically achieve cognitive maturity by mid-adolescence while psychosocial skills, such as impulse control, continue developing into the early 20s (Icenogle et al., 2018). For this reason, clinicians should recommended that parents stay involved throughout this developmental period, and gradually allow their adolescent to take independent responsibility of diabetes tasks as they demonstrate improvements in regulatory skills.[36] As demonstrated in the present study, increases in impulse control are necessary to combat the drop in adherence and HbA1c that is often observed when youth begin to manage diabetes independently.

Acknowledgements:

This work was supported by T71MC30798 from the Maternal & Child Health Bureau (MCHB), as well as grant #1R01HD064638-01A1 awarded to the senior author from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD). The content is solely the responsibility of the authors and does not necessarily represent the official views of the MCHB, NICHD, or the National Institutes of Health.

We thank the children and parents who participated in this study. We also thank the Diabetes Center for Children and the Cystic Fibrosis Center at Children's Hospital of Philadelphia for supporting this program of research.

Abbreviations:

T1D	Type 1 Diabetes
HbA1c	Hemoglobin A1c

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Implications and Contribution

Transfer of diabetes responsibility (from parent to child) should occur in the context of developmental changes. Concurrent increases in youth responsibility and impulse control were associated with better adherence. Increases in both verbal ability and impulse control on occasions when youth acquire more responsibility were associated with better HbA1c.

Table 1.

Descriptive Characteristics of Study Sample (N=117)

	n	% or Mean (SD)
Age at baseline [a]		12.87 (2.53)
Gender (% Male)	51	43.6%
Racial Minority[b]		
No	69	58.9%
Yes	45	38.5%
Single-Parent Household		
No	90	76.9%
Yes	23	19.7%
Household Income		
Less than $20K	19	16.2%
$20-40K	13	11.1%
$41-60K	16	13.7%
$61-80K	14	12%
$81-100K	13	11.1%
More than $100K	33	28.2%
Parent full-time employment		
Not currently employed	28	23.9%
Employed part-time	28	23.9%
Employed full-time	58	49.6%
Diabetes diagnosis duration (years)		5.63 (3.53)
Insulin regimen		
Pump	46	39.3%
Premixed (70/30)	24	20.5%
Basal-bolus	47	40.2%

Note: Numbers may not add up to 100% due to missing data (i.e., parent refused response);

[a]Given the accelerated cohort design, the number of participants at each age cohort varied at baseline: 8 years (n=6); 9 years (n=11); 10 years (n=18); 11 years (n=13); 12 years (n=12); 13 years (n=10); 14 years (n=16); 15 years (n=18); 16 years (n=13).

[b]Approximately sixty-percent (n=69) of youth in the sample identified as Non-Hispanic White, 22% (n=25) Non-Hispanic Black, 10% (n=12) Hispanic, 5% (n=7) Non-Hispanic Biracial, and 1% (n=1) Asian. Given this distribution (and lack of variance within some racial categories), we decided to dichotomize race/ethnicity.

Table 2:

Models testing effect of predictors on youth-reported adherence.

Estimates	Model 1 Unconditional Growth Curve	Model 2 Covariates	Model 3 Time-Varying Predictors	Model 4 Resp * IC	Model 5 Resp * VA
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Intercept (i)	4.03 (0.04) ***	2.02 (0.25) ***	1.35 (0.23) ***	1.35 (0.21) ***	1.35 (0.23) ***
Slope (s)	−0.05 (0.02) **	−0.09 (0.11)	−0.04 (0.02) *	−0.03 (0.02) *	−0.04 (0.02) *
Within Person-Effect					
Responsibility	-	-	−0.20 (0.14)	−0.30 (0.14) *	−0.24 (0.19)
Impulse Control	-	-	0.18 (0.04) ***	0.10 (0.04) *	0.18 (0.04) **
Verbal Ability	-	-	0.004 (0.002)	0.01 (0.002) *	0.004 (0.003)
Resp *IC	-	-	-	0.66 (0.13) ***	-
Resp *VA	-	-	-	-	0.004 (0.01)
Between-Person Effect					
On Intercept (i)					
Baseline Age	-	−0.04 (0.02)	-	-	-
Baseline adherence	-	0.56 (0.05) ***	0.66 (0.06) ***	0.67 (0.05) ***	0.67 (0.06) ***
Racial Minority	-	−0.14 (0.05) **	−0.08 (0.06)	−0.07 (0.05)	−0.07 (0.06)
Income	-	0.03 (0.02)	-	-	-
Baseline Responsibility	-	-	−0.04 (0.12)	−0.04 (0.11)	−0.04 (0.11)
Baseline Impulse Control	-	-	0.01 (0.03)	0.01 (0.03)	0.01 (0.02)
Baseline Verbal Ability	-	-	0.01 (0.002)	0.00 (0.001)	0.001 (0.002)
On Slope (s)					
Baseline Age	-	0.00 (0.01)	-	-	-
Baseline adherence	-	0.03 (0.02)	-	-	-
Racial Minority	-	−0.04 (0.02)	-	-	-
Income	-	−0.03 (0.003) ***	−0.03 (0.002) ***	−0.02 (0.003) ***	−0.03 (0.003) ***
Baseline Responsibility	-	-	−0.10 (0.04) *	−0.09 (0.04) *	−0.10 (0.04) *
Baseline Impulse Control	-	-	−0.01 (0.01)	0.01 (0.01)	−0.004 (0.02)
Baseline Verbal Ability	-	-	0.001 (0.001) *	0.00 (0.00)	0.001 (0.002) *
Variances					
Within-Person	0.08 (0.01) ***	0.08 (0.01) ***	0.08 (0.01) ***	0.07 (0.01) ***	0.08 (0.01) ***
Between Person (i)	0.08 (0.02) ***	0.02 (0.01) +	0.01 (0.01)	0.003 (0.01)	0.004 (0.01)
Between-Person (s)	0.03 (0.01) ***	0.01 (0.001) ***	0.004 (0.001) **	0.003 (0.001) *	0.01 (0.001) ***
Model Fit					
−2LL	482.82	292.74	134.11	109.05	134.00
BIC	501.10	334.33	175.78	153.03	177.99
df	6	14	18	19	19

Note: Responsibility (Resp) is based on YOUTH report. IC= impulse control; VA=verbal ability.

+ $p<0.10$;

* $p<0.05$;

** $p<0.01$;

*** $p<0.001$.

Table 3:

Models testing effect of predictors on parent-reported adherence.

Estimates	Model 1 Unconditional Model	Model 2 Covariates	Model 3 Time-Varying Predictors	Model 4 Resp * IC	Model 5 Resp * VA
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Intercept (i)	3.95 (0.04) ***	3.94 (0.03) ***	3.96 (0.03) ***	3.96 (0.03) ***	3.96 (0.03) ***
Slope (s)	−0.06 (0.01) ***	−0.04 (0.01) ***	−0.04 ***	−0.04 (0.01) ***	−0.04 (0.01) ***
Within-Person Effect					
Responsibility	-	-	0.14 (0.15)	0.11 (0.17)	0.27 (0.19)
Impulse Control	-	-	−0.01 (0.04)	−0.02 (0.04)	−0.01 (0.04)
Verbal Ability	-	-	0.001 (0.002)	0.001 (0.002)	0.002 (0.003)
Resp *IC	-	-	-	0.07 (0.17)	-
Resp *VA	-	-	-	-	−0.02 (0.01)
Between-Person Effect					
On Intercept					
Baseline adherence	-	0.70 (0.06) ***	0.78 (0.05) ***	0.78 (0.05) ***	0.78 (0.05) ***
Baseline Responsibility	-	-	−0.07 (0.12)	−0.07 (0.12)	−0.08 (0.12)
Baseline Impulse Control	-	-	−0.01 (0.03)	−0.01 (0.03)	−0.01 (0.03)
Baseline Verbal Ability	-	-	0.002 (0.001) *	0.002 (0.001) *	0.002 (0.001) *
On Age Slope					
Baseline adherence		−0.03 (0.02)	-	-	-
Income	-	0.001 (0.001)	-	-	-
Baseline Responsibility	-	-	−0.03 (0.03)	−0.03 (0.03)	−0.03 (0.03)
Baseline Impulse Control	-	-	0.002 (0.01)	0.002 (0.01)	0.000 (0.01)
Baseline Verbal Ability	-	-	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Variances					
Within-person	0.09 (0.01) ***	0.08 (0.01) ***	0.09 (0.01) ***	0.09 (0.01) ***	0.09 (0.01) ***
Between-person (i)	0.12 (0.02) ***	0.05 (0.01) ***	0.01 (0.01)	0.001 (0.01)	0.001 (0.01)
Between-person (s)	0.004 (0.002) *	0.002 (0.002)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
Model Fit					
−2LL	437.41	260.44	116.51	116.33	115.24
BIC	455.66	287.14	152.31	154.516	153.42
df	6	9	15	16	16

Note: Treatment responsibility (Resp) is based on PARENT report. IC= impulse control; VA=verbal ability.

+ $p<0.10$;

* $p<0.05$;

** $p<0.01$;

*** $p<0.001$.

Table 4:

Models testing effect predictors on glycemic control (HbA1c), with treatment responsibility based on youth report.

Estimates	Model 1 Unconditional Model	Model 2 Covariates	Model 3 Time-Varying Predictors	Model 4 Resp * IC	Model 5 Resp * VA
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Intercept (i)	9.01 (0.14) ***	8.18 (0.21) ***	8.48 (0.24) ***	8.50 (0.23) ***	8.43 (0.24) ***
Slope (s)	0.13 (0.04) **	0.15 (0.04) ***	0.26 (0.07) **	0.26 (0.07) ***	0.23 (0.07) ***
Within Person-Effect					
Responsibility	-	-	0.39 (0.54)	0.65 (0.54)	1.51 (0.71)
Impulse Control	-	-	−0.10 (0.15)	0.14 (0.17)	−0.15 (0.15) *
Verbal Ability	-	-	−0.01 (0.01)	−0.02 (0.01) +	−0.01 (0.01)
Resp *IC	-	-	-	−1.64 (0.60) **	-
Resp *VA	-	-	-	-	−0.10 (0.04) *
Between-Person Effect					
On Intercept					
Racial/Ethnic minority	-	1.28 (0.28) ***	0.99 (0.30) *	0.98 (0.29) ***	0.95 (0.29) ***
Single Parent	-	0.16 (0.34)	-	-	-
Basal-bolus	-	0.66 (0.29) *	0.59 (0.29) *	0.56 (0.29) *	0.56 (0.29) +
Premixed (70/30)	-	0.36 (0.36)	0.15 (0.36)	0.15 (0.36)	0.20 (0.36)
Baseline Responsibility	-	-	−0.80 (0.58)	−0.82 (0.57) +	−0.66 (0.58)
Baseline Impulse Control	-	-	0.06 (0.16)	0.08 (0.16)	0.06 (0.16)
Baseline Verbal Ability	-	-	−0.01 (0.01) +	−0.01 (0.01) +	−0.01 (0.01) +
Variances					
Within-Person	1.04 (0.11) ***	1.05 (0.11) ***	1.06 (0.13) ***	1.03 (0.12) ***	1.04 (0.12) ***
Between Person (i)	1.90 (0.31) ***	1.31 (0.24) ***	1.19 (0.23) ***	1.15 (0.23) ***	1.16 (0.23) ***
Between Person (s)	0.01 (0.03)	0	0	0	0
Model Fit					
−2LL	1083.75	1028.88	862.82	855.47	857.07
BIC	1096.57	1049.14	893.44	888.44	890.04
df	5	8	13	14	14

Note: Treatment responsibility (Resp) is based on YOUTH report. IC= impulse control; VA=verbal ability.

+ p<0.10;

* p<0.05;

** p<0.01;

*** p<0.001.

Table 5:

Models testing effect of predictors on glycemic control (HbA1c), with treatment responsibility based on parent report.

Estimates	Model 1 Unconditional Model	Model 2 Covariates	Model 3 Time-Varying Predictors	Model 4 Resp * IC	Model 5 Resp * VA
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Intercept (i)	9.01 (0.14)***	8.18 (0.21)***	8.48 (0.24)***	8.48 (0.24)***	8.50 (0.24)***
Slope (s)	0.13 (0.04)**	0.15 (0.04)***	0.26 (0.07)**	0.26 (0.07)**	0.27 (0.07)**
Within Person-Effect					
Responsibility	-	-	−0.25 (0.65)	−0.29 (0.70)	−0.51 (0.80)
Impulse Control	-	-	−0.07 (0.15)	−0.08 (0.17)	−0.06 (0.15)
Verbal Ability	-	-	−0.01 (0.01)	−0.01 (0.01)	−0.02 (0.01)
Resp *IC	-	-	-	0.12 (0.71)	-
Resp *VA	-	-	-	-	0.03 (0.06)
Between-Person Effect					
On Intercept					
Racial/Ethnic minority		1.28 (0.28)***	0.99 (0.30)***	0.99 (0.30)***	0.99 (0.30)***
Single Parent		0.16 (0.34)	-	-	-
Basal-bolus		0.66 (0.29)*	0.61 (0.30)*	0.61 (0.30)*	0.60 (0.30)*
Premixed (70/30)	-	0.36 (0.36)	0.23 (0.37)	0.23 (0.37)	0.22 (0.37)
Baseline Responsibility	-	-	−0.55 (0.69)	−0.56 (0.69)	−0.57 (0.69)
Baseline Impulse Control	-	-	0.08 (0.16)	0.08 (0.16)	0.09 (0.16)
Baseline Verbal Ability	-	-	−0.01 (0.01)*	−0.02 (0.01)*	−0.02 (0.01)*
Variances					
Within-Person	1.04 (0.11)***	1.05 (0.11)***	1.07 (0.13)***	1.08 (0.13)***	1.07 (0.13)***
Between Person (i)	1.90 (0.31)***	1.31 (0.24)***	1.20 (0.24)***	1.20 (0.24)***	1.42 (0.27)***
Between Person (s)	0.01 (0.03)	0	0	0	0
Model Fit					
−2LL	1083.75	1028.88	865.76	865.73	865.45
BIC	1096.57	1049.14	896.38	898.71	898.43
df	5	8	13	14	14

Note: Treatment responsibility (Resp) is based on PARENT report. IC= impulse control; VA=verbal ability.

+ p<0.10;

* p<0.05;

** p<0.01;

*** p<0.001.