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Executive Function Predicting Longitudinal Change in Type 1 Diabetes Management During the Transition to Emerging Adulthood

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OBJECTIVE

The objective of this study was to examine *1*) whether teens' glycemic control and adherence to type 1 diabetes treatment regimen worsen during the transition from late adolescence to emerging adulthood, and *2*) whether teens' executive function (EF), as measured by performance and self-reported problems with EF, is predictive of these changes (after controlling for general intelligence).

RESEARCH DESIGN AND METHODS

High school seniors with type 1 diabetes (*N* = 236; mean age 17.74 years) were assessed at three yearly time points. At baseline, during the senior year of high school, participants completed a self-report measure of problems with EF and performance-based measures of EF and general intelligence (IQ). Glycemic control was determined on the basis of results collected from HbA_{1c} assay kits, and teens reported their adherence at all three time points.

RESULTS

HbA_{1c} increased significantly across the three time points and adherence declined. EF performance was not associated with adherence or HbA_{1c} at baseline, nor with changes in adherence over time. However, better EF performance predicted slower increases in HbA_{1c} over time (i.e., slope) while controlling for IQ. Teens' self-reported problems with EF were associated with worse glycemic control and poorer adherence at baseline (i.e., intercept), but they did not predict changes in either HbA_{1c} or adherence over time (i.e., slope).

CONCLUSIONS

Abilities involved in performance on EF tests may be one resource for maintaining better glycemic control during the transition to emerging adulthood. Assessment of such EF abilities may allow for the identification of individuals who are most at risk for deterioration of glycemic control during this transition.

The transition between late adolescence and emerging adulthood has been described as a "high-risk" time for individuals managing type 1 diabetes (1), characterized by higher levels of HbA_{1c} and poorer adherence than for individuals at other developmental time periods (2). Longitudinal studies indicate that glycemic control (3,4) and adherence (5) deteriorate during adolescence. The few studies that have examined longitudinal trajectories extending into early young adulthood suggest these vary greatly across individuals, with some displaying increases in HbA_{1c} during

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adolescence and young adulthood (6,7), others showing improvements during young adulthood (6,7), and yet others maintaining fairly stable (high or low) levels of glycemic control and adherence across time (6–8). Understanding factors that contribute to such variability may help to identify those who are at highest risk for poor diabetes self-management during this transitional time.

Cognition may be an important factor in understanding adherence and glycemic control trajectories during the transition to emerging adulthood, a factor that to our knowledge has not yet been examined. During emerging adulthood, defined as the period from ages 18 to 25 years (9), teens need to remember, plan, and execute an intensive diabetes treatment regimen, often while moving away from home, entering college or the workforce, and establishing new relationships with peers (10). Cross-sectional research has demonstrated that general cognitive abilities and executive function (EF) abilities such as planning, organization, and working memory may provide adolescents with resources for maintaining better glycemic control and adherence. Specifically, in adolescents, more reported problems with EF (measured on the basis of reports by parents or youths) are associated with poorer adherence and poorer glycemic control (11–15). Previous cross-sectional results from the sample used in this study showed that lower scores on performance-based measures of EF were associated with poor glycemic control during the senior year of high school (15). Cross-sectional findings are supported further by longitudinal research showing that fewer parent-reported problems with EF characterized a low-risk group of adolescents who maintained good glycemic control across a 3-year time frame (16).

What is missing from the literature are longitudinal studies examining how EF specifically (controlling for general cognitive abilities) may be a resource for diabetes management across the transition to emerging adulthood, comparing performance-based measures to self-reported measures of problems with EF. Such research is important for three reasons. First, the vast majority of studies used questionnaires (self- or parent-report) that are purported to assess neurocognitive processes, but such measures are only modestly related to performance-based measures of EF (17,18). Thus, although questionnaires are easier to administer in clinic settings than performance-based measures, it is uncertain whether both are similarly predictive of changes in adherence and glycemic control over time. Second, studies have predominantly used parent-reported EF because of the young age of children, their cognitive impairments, or both (18). During emerging adulthood, teens' reports may be crucial to identifying those who are at risk, as parents often no longer attend their teens' health care visits and may be less knowledgeable about teens' daily lives. Finally, to understand whether EF specifically predicts diabetes management, more general cognitive abilities such as IQ must be statistically controlled, as IQ underlies many daily activities and is associated with both self-report and performance-based measures of EF (19).

This longitudinal study fills this important gap by examining how both self-reported problems with EF and performance-based measures of EF (while controlling for intelligence) predict longitudinal trajectories of type 1 diabetes management during the transition from late adolescence to early emerging adulthood. We first examine whether HbA_{1c} and adherence systematically change across three annual time points. We anticipated that significant increases in HbA_{1c} and decreases in adherence would occur, but that the rate of deterioration would vary across individuals. Next, we assessed whether teens' reports of problems with EF and performance-based measures of EF obtained during the senior year of high school (controlling for intelligence) predicted changes in HbA_{1c} and adherence across the three time points. We anticipated that both fewer self-reported problems with EF and higher EF performance would predict slower increases in HbA_{1c} and slower decreases in adherence over time.

RESEARCH DESIGN AND METHODS

Participants

High school seniors with type 1 diabetes were recruited for a 2-year longitudinal, multisite study investigating the transition to early emerging adulthood. Participants were recruited from outpatient pediatric endocrinology clinics during clinic visits or by phone in two southwestern U.S. cities. Youths were eligible if they had been diagnosed with type 1 diabetes for at least 1 year (mean $\pm$ SD time since diagnosis 7.35 $\pm$ 3.88 years; 94% of teens had diabetes for $\geq$2 years), spoke English as their primary language, were in their final year of high school, lived with a parent or parental figure at baseline (68.4% lived at home with both parents; 27.1%, with one biological parent; 4.5%, with adoptive parents or grandparents), would be able to have regular contact with parents or the parental figure over the subsequent 2 years, and had no condition that would prohibit study completion (e.g., severe intellectual disability, blindness). Adolescents who had dropped out of high school were eligible if they met all other criteria. Of the 507 qualified individuals we approached, 301 (59%) agreed to participate. Of those who initially agreed, 247 (82%) enrolled in the study. Reasons for not participating included lack of interest (33%) or being too busy during their senior year to participate (34%); 20% declined to give a reason. The institutional review board at one site permitted data collection to allow comparisons between those who did and those who did not participate. We found no differences in HbA_{1c}, time since diagnosis, sex, or pump status ($P > 0.05$). However, participants were slightly younger (mean $\pm$ SD 17.77 $\pm$ 0.43 vs. 17.91 $\pm$ 0.48 years; $t[203] = 2.27$; $P = 0.02$) and were more likely to be Hispanic (21% vs. 11%; χ^2 [1] = 3.88; $P = 0.049$) than nonparticipants.

Procedure

The study had institutional review board approval; parents provided consent and teens provided consent or assent (those who assented provided consent after they turned 18). EF performance and IQ were assessed in the laboratory, and an online survey measured self-reported problems with EF and adherence. Teens were paid $50 for the first two annual assessments and $75 for the third assessment. At each time point, teens reported illness and demographic variables, including their pump status, with whom they were living, and their health insurance. Because extreme hyperglycemia and hypoglycemia can affect

cognitive performance (20,21), blood glucose levels were checked before performance measures were completed. If blood glucose levels were outside the range 75–400 mg/dL, participants took steps to normalize blood glucose; testing was rescheduled for one participant who could not bring blood glucose in range. Blood glucose levels during the testing sessions were not related to performance measures of EF and IQ ($r < 0.13$; all $P > 0.11$).

Measures

EF

Self-reported problems with EF were measured with the Behavior Rating Inventory of Executive Function–Self-Report. This measure is normed for respondents between 5 and 18 years of age (22), and previous research has demonstrated its high internal consistency (α = 0.72–0.96). Participants rated items (0 = never, 1 = sometimes, 2 = often) to indicate how frequently they experienced each problem over the preceding 6 months. Subscales were combined into a global executive composite score with good reliability (α = 0.95). Age- and sex-corrected *t* scores taken from the manual (22) were used in analyses.

Performance-based EF was measured through the use of four subtests from the Delis-Kaplan Executive Function System battery (23). We assessed widely recognized components of EF: set maintenance and working memory, assessed with the Trail Making Test (letter–number sequencing condition completion time); response inhibition and cognitive control, assessed with the Color-Word Interference Test (inhibition and inhibition/switching condition completion times); and initiation and generative fluency, assessed with tests of verbal fluency (correct responses for the letter and category conditions) and design fluency (correct responses for each of the three conditions). This assessment battery yielded eight executive scores. The mean of norm-based, age-corrected, scaled scores (as described in the test manual [23]) was computed to generate a single EF performance score. In this sample, the Cronbach α for this composite was 0.83.

General IQ

Teens completed the Vocabulary subtest of the Wechsler Adult Intelligence Scale–Fourth Edition (24), which we used to estimate crystallized IQ (25). This subtest correlates 0.91–0.92 with verbal IQ and 0.79–0.81 with full-scale IQ in this age-group (24). Reported split-half reliability for the Vocabulary subtest is 0.93 for teens aged 16–19 years in the normative sample (24). We analyzed norm-based, age-corrected, scaled scores (24).

Adherence

Teens' reports of adherence to their diabetes regimen were measured through the use of the Diabetes Behavior Rating Scale, a 37-item scale assessing self-management behaviors (e.g., meal planning, blood glucose testing, exercise, the amount and timing of insulin) and components of problem-solving (e.g., adjusting insulin doses depending on blood glucose levels or food intake) (26). This measure correlates highly with more time-intensive interview measures (26). In this study, the scale had good reliability (α = 0.84 for teens who use an insulin pump; α = 0.86 for teens who do not use a pump). Scores were computed as proportions ranging from 0 to 1 (higher scores reflected better adherence) (26).

Glycemic Control

HbA_{1c} was measured on the day of cognitive testing and at later time points through the use of mail-in HbA_{1c} kits (provided and processed by CoreMedica Laboratories, accredited by the College of American Pathologists; www.coremedicalabs.com). This approach was chosen over obtaining HbA_{1c} from medical records to ensure that HbA_{1c} was measured on the day of cognitive testing for all participants, that the same procedures were used to measure HbA_{1c} across time points, and that HbA_{1c} measures could be obtained even from those who were not receiving routine care. The kit was completed by the teen at baseline after they received instructions from a trained research assistant, who observed test completion. This measure was highly correlated with HbA_{1c} obtained from point-of-care assays noted in the medical records at baseline (r = 0.74; $P < 0.001$).

Analytic Plan

Missing data for key study variables ranged from a low of 1% to a high of 12%. To account for missing data, we generated five data sets through multiple imputation (MI) (27) for individuals who provided survey data. We did not impute data for an individual who was missing all data from one time point. The MI procedure included variables beyond those included in the analyses presented here to help ensure that an adequate missing-at-random model was generated. The lowest efficiency was 0.942, suggesting that the MI procedure across five data sets adequately recovered missing data.

Unconditional linear growth curve models of HbA_{1c} and adherence were conducted with the MIXED command in SPSS software version 24 (IBM). Full maximum likelihood was applied to examine changes in HbA_{1c} and adherence across the three time points. We included random effects on the intercept and slope, with baseline coded as 0, such that the intercept represented the mean value of the dependent variable at time 1. Next we created conditional growth curve models to determine whether EF predicted baseline levels (i.e., intercept) and changes in HbA_{1c} or adherence (i.e., slope); we analyzed separate models for EF performance and self-reported problems with EF. All independent variables were centered at their mean to facilitate interactions (e.g., EF predicting slope or a time effect). We examined the conditional effects after controlling for IQ. Time since diagnosis and insulin pump status (0 = no, 1 = yes) measured at baseline were included as covariates in analyses of HbA_{1c}. Because 13% of individuals changed their pump status over time, pump status was analyzed as a time-varying covariate and results were similar to those with pump status controlled only at baseline.

No significant effects were found for sex across all analyses ($P > 0.10$). Hispanic/Latino participants had higher HbA_{1c} than did Caucasians at baseline (8.97% vs. 8.10%; $P < 0.05$), but the slope of HbA_{1c} did not differ between the groups. Analyses conducted with and without ethnicity as a covariate yielded no differences in results. Living in the parental home was not associated with either HbA_{1c} or adherence, nor did it alter the trajectories of these variables across time. Because these covariates were either not significant or did not alter results, they were not included in further analyses.

RESULTS

Preliminary Analyses

Consistent with the population at participating clinics, 75.2% of the full sample (N = 247) identified as non-Hispanic white, 14.2% as Hispanic, and 4.8% as African American; the remainder identified as Asian/Pacific Islander, American Indian, or more than one race. Patients were a mean of 17.76 years old (SD = 0.39 year), and 60% were female.

This study included 220 teens with complete survey data at two or more annual assessments and valid scores for EF performance, IQ, and self-reported problems with EF at baseline. Educational background of mothers and fathers was, on average, some college or higher (Table 1). Around 40% of teens were using a pump over time, and about half were living in the parental home at times 2 and 3. The majority of teens reported being either fully or partially covered by their parents' insurance. The 220 teens included in these analyses (63% female; mean ± SD age 17.77 ± 0.39 years) did not differ from the 16 who were not included (because they completed only a single time point) on primary study variables at baseline, including adherence, self-reported problems with EF, or EF performance ($P >$ 0.4); however, those included had lower HbA_{1c} at baseline than those who completed a single time point (8.23% vs. 8.92%; t = 2.36; $P < 0.05$).

Teens had, on average, HbA_{1c} values above American Diabetes Association recommendations ($HbA_{1c} \leq$7.5% [28]) in all years of the study (Table 1). Teens' reports of problems with EF and of EF performance and IQ were in the mean range relative to norms (22–24). More self-reported problems with EF were modestly associated with poorer EF performance ($r = -0.28$; $P < 0.01$).

Table 1—Descriptive statistics for demographics and primary measures

	Baseline		Year 2		Year 3	
Mother's education, %						
High school or less	13.900		—		—	
Some college	42.800		—		—	
Bachelor's or higher	42.500		—		—	
Father's education, %						
High school or less	21.300		—		—	
Some college	28.800		—		—	
Bachelor's or higher	48.300		—		—	
Uses pump, %	43.600		45.000		51.200	
Living in parental home, %	100.000		52.510		48.470	
On parents' insurance, %	75.000		78.600		72.000	
	Mean	SD	Mean	SD	Mean	SD
HbA_{1c}						
In %	08.218	1.668	08.937	1.976	09.229	2.052
In mmol/mol	66.000		74.000		77.000	
Self-reported EF problems	54.306	10.524	—		—	
EF performance	11.312	2.038	—		—	
IQ	11.512	3.317	—		—	
Adherence	00.609	0.123	00.587	0.132	00.589	0.150

Scores for self-reported EF problems, EF performance, IQ, and adherence are based on the tests described in RESEARCH DESIGN AND METHODS. Dashes indicate that the variable was only measured at baseline.

EF Performance and Self-Reported Problems With EF Predicting Change in HbA_{1c}

Growth models examining linear change in HbA_{1c} are presented in Table 2. The time effect in the unconditional growth model indicated that HbA_{1c} increased significantly over time, with a 0.507% increase in HbA_{1c} for each year past the senior year of high school (baseline). Significant random effects indicated between-person variability at baseline (intercept) and in changes in HbA_{1c} across time (slopes). Covariate analyses indicated that individuals using insulin pumps had lower HbA_{1c} than those not using pumps.

Conditional growth models indicated that higher IQ was associated with lower HbA_{1c} at baseline. Further, EF performance predicted change in HbA_{1c}

Table 2—Growth curve model for HbA_{1c}

HbA_{1c} growth curve models	β	SE	Random effect	Variance
Unconditional model				
Intercept	8.267	0.108**	1.368	0.216**
Years since diagnosis	0.038	0.025		
Pump status (0 = MDI, 1 = pump)	−0.844	0.196**		
Time (0 = time 1)	0.507	0.072**	0.347	0.101**
Conditional models				
EF Performance[a]				
Intercept	8.271	0.104**	1.196	0.198**
Years since diagnosis	0.034	0.024		
Pump Status (0 = MDI, 1 = pump)	−0.662	0.191**		
Time (0 = Time 1)	0.502	0.071**	0.340	0.097**
IQ				
On Intercept	−0.096	0.038*		
On Slope	0.048	0.026		
EF Performance				
On Intercept	−0.066	0.060		
On Slope	−0.096	0.043*		
Self-reported EF problems[a]				
Intercept	8.269	0.102**	1.105	0.192**
Years since diagnosis	0.035	0.024		
Pump status (0 = MDI, 1 = pump)	−0.706	0.189**		
Time (0 = time 1)	0.499	0.072**	0.382	0.101**
IQ				
On Intercept	−0.107	0.033**		
On Slope	0.020	0.023		
Self-reported EF problems				
On Intercept	0.029	0.010**		
On Slope	0.002	0.007		

MDI, multiple daily injections. [a]Controlling for IQ. *$P < 0.05$; **$P < 0.01$.

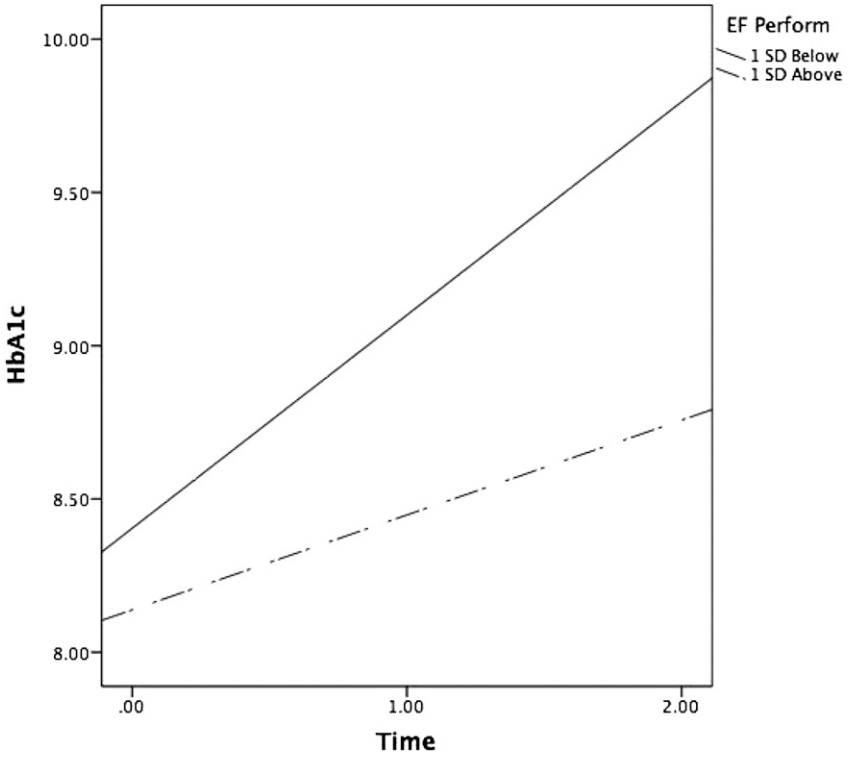

Figure 1—Changes in HbA_{1c} over time as a function of EF performance (EF Perform; 1 SD above and below the mean).

(EF performance on slope effect; Table 2), indicating that EF performance predicted significantly different slopes in HbA_{1c} across time. As displayed in Fig. 1, individuals with higher EF performance at baseline experienced slower increases in HbA_{1c} across the three time points (plotted 1 SD above and below the mean EF performance). Simple slope analyses revealed that both slopes were significantly different from zero, indicating that both those with better and those with poorer EF performance experienced increases in HbA_{1c} across the three time points. As predicted, however, those with better EF performance deteriorated slower (slope of 0.361%) than those with poorer EF performance (slope of 0.622%).

A similar analysis was conducted using self-reported problems with EF. As displayed in Table 2, both higher IQ and fewer self-reported problems with EF were associated with lower HbA_{1c} at baseline. However, self-reported problems with EF did not predict changes in HbA_{1c} across time.

EF Performance and Self-Reported Problems With EF Predicting Change in Adherence

Growth models examining linear change in adherence are presented in Table 3. The unconditional growth model indicated that adherence decreased significantly over time, with a very small decrease of 0.012 for each year past the senior year of high school. Random effects were statistically significant, indicating between-person variability at baseline (intercept) and in changes in adherence across time (slope). Neither IQ nor EF performance predicted intercepts or slopes for adherence across time.

A similar analysis was conducted using self-reported problems with EF. As displayed in Table 3, greater self-reported problems with EF were associated with lower adherence at baseline. No variable predicted slopes of adherence across time.

CONCLUSIONS

The findings of this study support the view of the transition to early emerging adulthood as a "high-risk" time for diabetes management (1). HbA_{1c} increased substantially during early emerging adulthood. This increase is clinically concerning given that at baseline teens were already well above American Diabetes Association–recommended HbA_{1c} values. Substantial variability existed in the slopes of HbA_{1c}, with HbA_{1c} in some individuals increasing more rapidly than in others, consistent with the growing literature on variability in glycemic control across the transition to emerging adulthood (5–7). Teens also reported lower adherence during their senior year than was reported in a sample of 12- to 18-year-olds (0.61 vs. 0.75 out of 1.00) (26), with further modest declines in adherence across time.

This study is to our knowledge the first to demonstrate that better scores on a performance-based measure of EF predict slower increases in HbA_{1c} over time, even when controlling for intelligence. Our participants scored within the mean range for EF relative to national norms, indicating that EF performance even within the normal range is important in understanding changes in HbA_{1c} across time. EF performance likely would be more predictive if examined in individuals with scores in the clinically impaired range (29). The fact that the performance-based measure predicted change even when controlling for intelligence provides evidence that EF specifically, rather than cognition more generally, is predictive of HbA_{1c} changes across time. Although performance-based EF scores predicted changes in HbA_{1c} across time, the slope of HbA_{1c} still varied significantly. Such findings suggest that other factors are involved in changes in HbA_{1c} during emerging adulthood, such as health care appointments and changes in parental involvement or other support—many of which we did not have access to in this study (e.g., severe hypoglycemic episodes, diabetic ketoacidosis). These factors will be important to include in future research.

Self-reported problems with EF were associated with HbA_{1c} and adherence at baseline, but not with changes in HbA_{1c} or adherence across the 2-year period. The modest correlation between EF performance and self-reported problems with EF in this study is consistent with the broader literature about younger children and those with developmental disorders (18). The neurocognitive processes needed for execution of self-reported versus performance-based tasks likely differ, as functional MRI research demonstrates that such measures activate different neuroanatomical regions (30). Self-report measures

Table 3—Growth Curve Model for Adherence

Components of adherence growth curve models	Adherence β	Adherence SE	Random effect	Variance
Unconditional model				
Intercept	0.604	0.008**	0.010	0.001**
Time (0 = time 1)	−0.012	0.005*	0.002	0.001**
Conditional models				
EF performance[a]				
Intercept	0.604	0.008**	0.010	0.001**
Time (0 = time 1)	−0.011	0.005*	0.002	0.000**
IQ				
On Intercept	0.000	0.003		
On Slope	0.001	0.002		
EF performance				
On Intercept	0.005	0.005		
On Slope	0.000	0.003		
Self-reported EF problems[a]				
Intercept	0.604	0.008**	0.009	0.001**
Time (0 = time 1)	−0.010	0.005	0.002	0.000**
IQ				
On Intercept	0.000	0.002		
On Slope	0.001	0.001		
Self-reported EF problems				
On Intercept	−0.004	0.001**		
On Slope	0.000	0.000		

All units are proportions as adherence ranges from 0–1. [a]Controlling for IQ. *$P < 0.05$; **$P < 0.01$.

of EF problems have been described as tapping typical behavior in real-world contexts and reflect factors other than EF abilities, including contextual factors such as available resources (e.g., support from parents) or the complexity of one's daily life. By contrast, performance-based EF measures reflect underlying neurocognitive capacity assessed under constrained, structured conditions (18), and thus they are relatively nonconfounded by contextual factors. The results suggest that it is the extent to which emerging adults can engage in EF optimally across contexts that allows them to maintain good glycemic control throughout emerging adulthood. The discrepancy between self-reported EF performance and problems with EF could be due to teens underestimating or misremembering their problems with EF. Scores from self-report and performance-based measures of EF clearly represent different constructs and should not be interpreted as commensurate (17,18).

Neither teens' reported EF performance nor problems with EF were predictive of changes in adherence across time; this perhaps is attributable to the limited changes in self-reported adherence across the 2 years. The large increases in HbA_{1c} and the very modest declines in adherence indicate that emerging adults' perceptions of adherence do not correspond with their HbA_{1c} values. Young emerging adults may be adhering in the same manner as they did during adolescence but without the same beneficial result for HbA_{1c}. Contextual changes in early emerging adulthood, including the reduced involvement of parents, may alter the efficacy of their adherence behaviors. In addition, emerging adults' judgments of their adherence are only modestly related to more objective measures such as blood glucose tests (31). Future research on individuals in this age range would benefit from objective measures such as records downloaded from glucometers, continuous glucose monitors, or insulin pumps, which were not available for this sample.

The current findings have numerous clinical implications. First, teens' EF performance may be a useful indicator of who is at increased risk for deteriorations in glycemic control during the transition out of high school. The fact that only EF performance—rather than self-reported problems with EF—was predictive is important, as most research has used self- or parent-report measures such as the Behavior Rating Inventory of Executive Function. Although traditional measures of EF performance cannot realistically be administered by medical personnel, the field of clinical neuropsychology is actively developing computer-administered tests that could be adapted for clinical use (32). Currently, however, batteries that are partially (e.g., the National Institutes of Health Executive Abilities: Measures and Instruments for Neurobehavioral Evaluation and Research or the Cognition Battery from the NIH Toolbox [33,34]) or fully (e.g., the Cambridge Neuropsychological Test Automated Battery [35]) computerized are primarily appropriate for use in research. Growing evidence that performance measures of cognition (including EF) contribute to glycemic control, and that diabetes itself has a deleterious impact on cognition (36), suggest that neuropsychological evaluations may be beneficial in identifying those who are at risk for poor health outcomes. Such evaluations, together with tailored feedback, have been associated with improved patient outcomes in a variety of settings (37).

The results of this study should be interpreted in the context of some limitations. First, although we used a composite of eight EF performance–based scores, we did not comprehensively assess all aspects of the EF construct, especially emotional control and decision making (19). Second, we assessed EF performance at only one time point. Although the longitudinal design of the study provides some assurance that EF performance did affect changes in HbA_{1c}, emerging adulthood is a time when EF is still developing. Because deteriorations in HbA_{1c} and the frequency of severe hypoglycemia may have consequences for cognitive function (36), additional research reassessing EF during emerging adulthood is necessary in order to understand the bidirectional associations between EF and glycemic control (36). Third, the majority of teens in the sample had parents who had attained at least some college education, which may limit generalizability to teens who have fewer advantages and whose EF may have been negatively affected by low socioeconomic status (38). Finally, by design, our participants were enrolled during their senior year of high school (ages 17 and 18 years), which limits the generalizability of the findings to those of other ages.

In sum, this study demonstrates that EF is a resource for good glycemic control across the high-risk time of emerging adulthood. The challenges that emerging adults with low EF face may be compounded by the concomitant decline in parental involvement that often occurs during this time. Early emerging adults (especially those with low EF abilities) may benefit from multiple supports for diabetes management, such as text-based reminders (39) and the support and assistance that parents, friends, and health care providers may provide, in order to facilitate their adherence behaviors and maintain good glycemic control during this transitional time (40).

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Author Contributions. C.A.B., D.J.W., Y.S., and J.B. designed the study. C.A.B., J.B., and A.M. analyzed data. Y.S., S.L.T., and A.H.L. performed the literature search and acquired data. P.C.W. and M.M. facilitated clinic recruitment. C.A.B., D.J.W., Y.S., S.L.T., J.B., A.M., A.H.L., P.C.W., and M.M. wrote and critically revised the manuscript and approved the manuscript for submission. C.A.B. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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