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Delay discounting associated with challenges to treatment adherence and glycemic control in young adults with type 1 diabetes

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Abstract

Introduction: Many young adults with type 1 diabetes (T1D) face challenges in adherence to self-management practices and have above-target HbA1c. Poorer decision-making skills, indicated by greater delay discounting, may be linked to these factors.

Methods: An online survey using social media ads targeted young adults aged 18–26 with T1D. Participants completed the Self-Care Inventory and the 5-trial delay discounting task and self-reported their last HbA1c value.

Results: Discounting was significantly associated with treatment adherence ($r = -.14, p < .05$) and HbA1c ($r = .18, p < .01$). Adherence was also associated with HbA1c ($r = -.26, p < .01$). In a hierarchical regression, adding discounting explained significant additional variance in HbA1c after controlling demographics ($F(1, 257) = 3.99, p < .05$); adding adherence next explained significant additional variance in HbA1c ($F(1, 256) = 12.96, p < .01$). In the final model, adherence significantly explained HbA1c variance ($\beta = -.21, p < .01$).

Discussion: These results expand the literature on cognitive factors and glycemic control among patients with T1D. Factors like delay discounting represent potentially modifiable risk factors targetable through interventions.

Keywords

adherence; delay discounting; HbA1c; type 1 diabetes; young adult

1. Introduction

Type 1 diabetes (T1D) affects as many as 3 million people in the US (Chiang et al., 2014), and is associated with an increased risk of mortality (Lind et al., 2014). HbA1c consistently above target is common for those with T1D. On average, young people with T1D aged 13–25 have higher HbA1c levels than either younger or older samples (Clements et al., 2016). Adherence to clinically recommended self-care routines is crucial for maintaining glycemic

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control (Hood et al., 2009; Karter et al., 2001) and improving health outcomes (Diabetes Control and Complications Trial Research Group, 1995). Barriers to adherence and glycemic control include a variety of social, psychological, and cognitive factors (Anderson & McKay, 2011). Cognitive factors associated with greater adherence and lower HbA1c include parent- and self-report measures of higher executive function (Duke & Harris, 2014) as well as more self-control (Hughes et al., 2012). Research on such factors is less common among young adults. Young adulthood is a developmental transition that can be challenging to patients with T1D as they must transition to adult clinics while increasingly managing their disease independent of support from parents (Lotstein et al., 2013; Helgeson et al., 2013).

One cognitive factor that may predict adherence and lower HbA1c is delay discounting, a decision-making construct with predictive utility across diverse health behaviors (Bickel et al., 2012). In delay discounting tasks, participants are asked to choose between a series of immediate and delayed rewards. Choices that favor immediate rewards over future rewards are used to calculate the delay discounting rate (Mazur, 1987). Our group recently conducted a study testing relations between discounting, adherence, and HbA1c among adolescents with T1D, all of whom had HbA1c $\geq 8.0\%$ (Lansing et al., 2017a). Lansing et al.'s (2017a) study ($N = 61$) showed an association between greater discounting and higher HbA1c. In the present study, we sought to replicate these findings in young adults with T1D. We used social media recruitment to obtain a national sample and included a novel, brief delay discounting task (Koffarnus & Bickel, 2014). Within this sample of young adults with T1D, we predicted that delay discounting would be associated with both adherence and HbA1c. We also predicted higher delay discounting for participants with above-target HbA1c ($\geq 8\%$) than near-target HbA1c ($< 8\%$).

2. Methods

2.1 Procedure and Participants

We administered an anonymous online survey via Qualtrics which collected information on self-reported HbA1c, self-care adherence, delay discounting, and demographics. Young adults with T1D were recruited for the survey using Facebook's proprietary algorithms, which advertised to users on Facebook, Instagram, and Facebook's Audience Network of third-party apps and websites. Clicking on the advertisement redirected participants to the Qualtrics survey's informed consent page. This page explained that the study was an anonymous survey about T1D. To ensure anonymity, we did not collect IP addresses.

Inclusion criteria were: being between 18 and 26 years of age and having a T1D diagnosis for 18 months or more. There were no exclusion criteria used. A total of 412 participants began the survey, and 405 provided consent. Of those, 314 met inclusion criteria and provided an HbA1c value. Overall, $N = 267$ participants were included in the analyses. The survey was administered for 31 non-consecutive days from March 5 to April 14, 2017. Respondents were not compensated. The Dartmouth Committee for the Protection of Human Subjects approved the study.

As shown in Table 1, participants were on average about 22 years old, and 51% had an HbA1c of < 8%. Mean HbA1c was 8.23% (SD = 1.66%). The sample was 45% male, and was mostly White, non-Hispanic (85%). Most participants (81%) had at least some college, and 71% used an insulin pump.

2.2 Measures

The delay discounting coefficient, k , was obtained using the 5-trial Delay Discounting task (Koffarnus & Bickel, 2014). Over five consecutive trials, participants chose whether to receive \$500 now or \$1,000 after a delay. The delay for the first choice was three weeks; for each new trial, the delay was adjusted based on the participant's previous response. Choosing \$500 now resulted in a shorter delay on the next trial; choosing \$1000 after the delay resulted in a longer delay. Based on choices made on the first four trials, there were 16 possible delays on the final trial, and the participant's choice of \$500 now or \$1000 at that final delay resulted in 32 (2^5) possible outcomes on the 5th trial. Each of those outcomes was assigned a k value provided in a table in Koffarnus & Bickel (2014). The raw k values were positively skewed, thus we used $\ln k$ values in analyses.

Treatment adherence was measured using the 14-item Revised Self-Care Inventory (SCI; Weinger et al., 2005). The SCI asked participants to rate how often they followed their diabetes treatment plan on a Likert scale of 1 (Never) to 5 (Always) based on the past 1–2 months. Sample items included “take insulin at the right time” and “eat meals/snacks on time.” Mean SCI item scores were used in all analyses. HbA1c was self-reported from participants' last clinic visit; possible values ranged from 6.0 to “14.0 or higher.” A total of $N = 2$ participants selected the highest value, which was scored as 14.0 in analyses.

2.3 Analyses

All analyses were conducted using IBM SPSS Statistics 23. The analyses included chi-square and t-tests for comparing demographic variables across groups of survey completers vs. non-completers and across groups of those with above-target ($\geq 8.0\%$) vs. near-target ($< 8.0\%$) HbA1c. Pearson's correlations were computed among delay discounting, adherence, and HbA1c.

To verify that the HbA1c-delay discounting relationship appeared linear, participants were divided into quartiles by HbA1c, and the quartiles' mean delay discounting rates ($\ln k$) were graphed and inspected. This visual analysis showed a linear relationship between delay discounting means across HbA1c quartiles. A hierarchical regression was conducted testing demographic variables, discounting, and adherence as predictors of HbA1c. Demographic variables of gender (0 = male; 1 = female), age (in years), and education (0 = high school degree or below; 1 = some college; 2 = associate's degree or above) were entered in Model 1, delay discounting ($\ln k$) was entered in Model 2, and adherence (mean SCI item scores) was entered in Model 3. These analyses address the questions of whether delay discounting explained significant incremental variance in HbA1c after accounting for demographic variables and whether adherence explained significant additional variance after accounting for demographic variables and delay discounting.

Of the $N = 314$ who met inclusion criteria and provided HbA1c, SCI and delay discounting data were available for $N = 267$ participants. The demographics characteristic questions came last in the survey; data for all variables were available for $N = 265$.

3. Results

3.1 Group differences: Survey completion

Chi-square and t-tests compared those who completed vs. did not complete the survey on insulin pump use, HbA1c, and age. Those who completed the survey did not have significantly different rates of insulin pump use ($\chi^2(1) = .17, p = .68$) or significantly different HbA1c ($t(312) = -.66, p = .51$). However, survey completers were significantly older than non-completers ($t(312) = -3.24, p < .01$).

3.2 Group differences: Above vs. near-target HbA1c

Table 1 includes t-test and chi-square comparisons of key outcome variables and demographic characteristics, based on whether participants reported near-target HbA1c ($< 8\%$) or above-target HbA1c ($\geq 8\%$). As expected, there was a significant group difference for discounting, with higher average discounting for participants with above-target HbA1c ($t(265) = 2.53, p < .05$). There was also a significant group difference on the SCI, with lower average adherence for those with above-target HbA1c ($t(265) = -4.44, p < .01$). In addition, those with more education were more likely to have near target HbA1c ($\chi^2(2) = 10.89, p < .01$) as were females ($\chi^2(1) = 4.26, p < .05$). Comparisons for age, race/ethnicity, and insulin pump use were not significant (see Table 1).

3.3 Continuous associations between demographics, discounting, adherence, and HbA1c

As hypothesized, higher discounting was associated with lower adherence ($r = -.14, p < .05$) and higher HbA1c ($r = .18, p < .01$), and higher adherence was associated with lower HbA1c ($r = -.26, p < .01$). For these bivariate correlations, $N = 267$.

A hierarchical regression was conducted to determine whether variance in HbA1c was explained by demographic factors, and whether adding discounting and adherence to the model accounted for significant incremental amounts of variance in HbA1c (Table 2). Education, gender, and age were entered in Model 1. Together, demographics accounted for 9.4% of the variance in HbA1c, $F(3, 258) = 8.97, p < .01$, and education was the only significant predictor of HbA1c. In Model 2, delay discounting explained an additional 1.4% of variance in HbA1c, significantly increasing R^2 , $F(1, 257) = 3.99, p < .05$. In Model 3, adherence accounted for an additional 4.3% of variance—also a significant increase in R^2 , $F(1, 256) = 12.96, p < .01$. In this final model, adherence and education were significant predictors of HbA1c. The final model accounted for 15.1% of the variance in HbA1c.

4. Discussion

Overall, this social media survey resulted in a sample of young adults with T1D who showed comparable glycemic control to other national samples. In our sample, 51% of participants

reported their most recent HbA1c to be near-target at $< 8\%$, comparable to 44% in a sample of young adults 18–25 years old in the T1D Registry (Beck et al., 2012).

The results of the current study showed that among young adults, higher delay discounting was significantly associated with lower adherence and higher HbA1c. The significant association between discounting and HbA1c was found both when comparing above target vs. near target groups and for associations across the full range of HbA1c. Although these findings could indicate that adherence mediates the relationship between delay discounting and HbA1c, longitudinal data are necessary to test this hypothesis.

No significant associations were found between HbA1c and survey completion, age, race/ethnicity, or insulin pump use; however, education consistently explained variance in HbA1c after controlling for all other variables in the final model. The association between education and HbA1c is consistent with other reports showing positive relations between executive function and HbA1c (Duke & Harris, 2014), and also a study showing a strong association between GPA and HbA1c (Lansing et al., 2017b). Such associations may reflect general self-control processes that support self-management of diabetes.

These results extend our group's previous findings of relations between discounting, adherence, and HbA1c in adolescents aged 13–17 with T1D and HbA1c $\geq 8.0\%$ (Lansing et al., 2017a). This earlier study reported significant associations between *lnk* (measured via a longer task) and HbA1c ($r = .39, p < .01$). Lebeau et al. (2016) also found similar relationships between delay discounting and HbA1c in older adults with type 2 diabetes ($r = 0.24, p < 0.05$). The present study extends these findings between HbA1c and delay discounting to include young adults exhibiting a wider range of glycemic control. The similarity of these findings across age ranges and types of disorders further evidences that the link between delay discounting and biometric outcomes generalizes to situations beyond those investigated in our study.

Furthermore, these studies suggest that delay discounting may be a useful target of interventions to improve adherence. One promising intervention involves episodic future thinking (EFT; Daniel et al., 2013, 2015). EFT involves imagining and pre-experiencing the future and its consequences by projecting oneself into the future (Atance & O'Neill, 2001). Daniel et al. (2013; 2015) showed that delay discounting and food consumption were reduced among overweight children and adults exposed to EFT. EFT interventions might be used to lower delay discounting in adolescents and young adults with T1D, perhaps leading to improved adherence and lower HbA1c. Interventions of this sort may be especially beneficial for young adults who are transitioning to greater social and financial independence and must therefore make independent efforts to plan for the future (Helgeson et al., 2013) while also experiencing higher discounting than older adults in the general population (Reimers et al., 2009).

4.1 Limitations

Because the sample was self-selected, it may not have been representative. Of note, 85% of respondents were White, non-Hispanic. No racial/ethnic groups were directly targeted for this survey. Future surveys of young adults with T1D using Facebook's targeted advertising

algorithms could be used to achieve a representative sample. Also, demographic variables were assessed at the end of the survey. This prohibits us from reporting the demographics of those participants ($N = 47$, 15% of the sample) who did not complete the survey.

HbA1c and adherence were assessed via self-report, and not objectively verified. We recommend replication of our findings using in-person HbA1c assessments and diabetes device data to assess adherence. Notably, HbA1c in both Lansing et al. (2017a) and Lebeau et al. (2016) was measured in person—not through self-report. The similarity between our findings and these are encouraging given the differences in methods of HbA1c assessment.

In addition, HbA1c and delay discounting were not collected at the same time, and the date of the last HbA1c test was not collected. However, any changes in HbA1c or discounting that may have happened since the date of the reported HbA1c would likely contribute nonsystematic (error) variance and thus decrease the strength of the association between these two variables—not increase it. In this cross-sectional study, we were not able to test whether glycemic control influences future delay discounting; we recommend longitudinal research to clarify this relationship.

5. Conclusion

Delay discounting is a promising target of research on T1D. Decreased delay discounting was shown to be associated with increased adherence and lower HbA1c for participants with a wide range of glycemic control. These findings extended previous research on the association between decreased discounting and lower HbA1c in adolescents. It is important to further study the mechanisms through which delay discounting affects glycemic control in this population.

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Highlights

- Delay discounting was measured for young adults with type 1 diabetes
- Delay discounting shows desire for smaller immediate (vs. larger delayed) rewards
- Higher delay discounting indicates greater preference for immediate rewards
- Discounting the future was associated with higher HbA1c

Table 1

Sample description and comparisons for above and near-target HbA1c levels

	Total Sample <i>N (%) / Mean (SD)</i>	Near Target HbA1c < 8% <i>N (%) / Mean (SD)</i>	Above Target HbA1c >= 8% <i>N (%) / Mean (SD)</i>	Test Statistic <i>t-value or $\chi^2(df)$</i>
Demographics				
Age	21.78 (2.60)	21.88 (2.57)	21.67 (2.65)	-.648 (265)
Gender ^a				4.264 (1) *
Male	119	53 (44.5)	66 (55.5)	
Female	143	82 (57.3)	61 (42.7)	
Race/Ethnicity				.124 (1)
White, Non-Hispanic	226	117 (51.8)	109 (48.2)	
Other	39	19 (48.7)	20 (51.3)	
Education ^b				10.889 (2) **
HS or less	51	18 (35.3)	33 (64.7)	
Some college	119	58 (48.7)	61 (51.3)	
Associate's degree or higher	95	60 (63.2)	35 (36.8)	
Insulin pump use				.460 (1)
Use a pump	190	100 (52.6)	90 (47.4)	
No pump use	77	37 (48.1)	40 (51.9)	
Outcome Measures				
ln(k)	-5.63 (1.84)	-5.90 (1.75)	-5.34 (1.89)	2.529 (265) *
Mean SCI	3.30 (.55)	3.44 (.51)	3.15 (.55)	-4.436 (265) **

Note: N = 267 for age, insulin pump use, and outcome variables; N = 262 for gender; N = 265 for all other demographic variables. SCI = Self-Care Inventory, $\ln(k)$ = Natural log of delay discounting k-value

^aThree participants indicated their gender as transgender or other; two of them indicated HbA1c >= 8%, while one indicated HbA1c < 8%. They are not included in the χ^2 analyses. Gender is provided for 262 participants.

^bParticipants who had indicated that their highest educational attainment was "high school degree" but whose occupation was "student" were coded as having "some college" for the education variable.

* $p < .05$;

** $p < .01$

Table 2

Summary of hierarchical regression analysis for variables predicting HbA1c

Variable	β	t	sr^2	R	R^2	R^2
Model 1				.307	.094	.094
Education	-.310	-4.622 **	.075			
Gender	-.104	-1.737	.011			
Age	.064	.941	.003			
Model 2				.329	.108	.014
Education	-.287	-4.249 **	.063			
Gender	-.097	-1.616	.009			
Age	.052	.763	.002			
Delay Discounting (<i>lnk</i>)	.120	1.998 *	.014			
Model 3				.389	.151	.043
Education	-.257	-3.856 **	.049			
Gender	-.089	-1.521	.008			
Age	.016	.239	.000			
Delay Discounting (<i>lnk</i>)	.096	1.631	.009			
Adherence (SCI mean item score)	-.212	-3.601 **	.043			

Note: $N = 262$;*
 $p < .05$ **
 $p < .01$