Patterns of Engagement With an Incentivized Text Messaging Intervention (MyDiaText) in Teens With Type 1 Diabetes in Suboptimal Control

Tara Kaushal,[1,2] Terri H. Lipman,[3–5] Lorraine E. Levitt Katz,[3,4] and Lori M.B. Laffel[1,2]

[1]Joslin Diabetes Center, Boston, MA; [2]Harvard Medical School, Boston, MA; [3]Children's Hospital of Philadelphia, Philadelphia, PA; [4]University of Pennsylvania Perelman School of Medicine, Philadelphia, PA; [5]University of Pennsylvania School of Nursing, Philadelphia, PA

Adolescents with type 1 diabetes are vulnerable to suboptimal glycemic control, generally due to insufficient self-care behaviors (1,2). Because they have some of the highest rates of mobile communication technology use (3), this modality may hold promise for providing reminders or encouragement to adolescents to engage in self-care. However, the effects of text messaging interventions on self-care and glycemic outcomes are mixed, with some reports favoring improvements in teen self-care behaviors such blood glucose monitoring frequency or medication adherence (4–7).

In an alternative attempt to reach this high-risk age-group, researchers have explored the use of financial incentives to promote self-care behaviors, which yielded some glycemic benefit in the short term (8,9). However, there is limited research on the combination of a financial incentive and a mobile health intervention (10,11) and the potential benefits that could accrue from blending these approaches. Nonetheless, use of either a unimodal or a bimodal intervention requires that adolescent recipients remain engaged with the program.

In this report, we describe adolescent engagement during a 6-month study of a psychoeducational text messaging intervention that incorporated financial incentives. The primary study included adolescents with type 1 diabetes in suboptimal control and showed a potential increase in self-reported self-care in those receiving the intervention as intended (10). This analysis of the primary study's intervention group described patterns of adolescent engagement with the intervention and identified factors associated with responsiveness. We also evaluated the potential impact of engagement on glycemic outcomes and self-care.

Research Design and Methods

This study analyzed 6 months of data from teenagers with type 1 diabetes receiving an incentivized text messaging intervention aimed at increasing education and support for diabetes self-care. Youths were eligible for inclusion if they were 12–18 years of age, had a duration of type 1 diabetes of at least 1 year, had had a clinic visit at the Children's Hospital of Philadelphia (CHOP) Diabetes Center for Children within the past 6 months, had an A1C ≥8.0%, had insurance approval for the point-of-care (POC) A1C testing at CHOP, understood English, and owned a mobile phone with unlimited text messaging. Adolescents with a major cognitive or organ disability or who had taken steroid medication in the past 3 months were ineligible. The full randomized controlled trial was registered on ClinicalTrials.gov (NCT02927639) and approved by the local institutional review board (#16-01332). Adolescents and parents provided written informed consent and assent as appropriate before beginning any study procedures. All study participants registered on MyDiaText™, a website with text-messaging capabilities using Twilio. At enrollment, they selected one AADE7 Self-Care Behavior (12) and were randomized 1:1 to the intervention or control arms.

Participants received one daily text message using Twilio REST API (representational state transfer application programming interfaces) services. Messages had been created by a multidisciplinary team of type 1 diabetes experts before study initiation. Participants received a combination of declarative text messages about their pre-selected self-care behavior goal, as well as quiz-type questions about general type 1 diabetes knowledge. They were asked to respond via text message to indicate that the message had been received. Every 2 weeks, one participant received a $10 reward via lottery drawn from the participants with the longest consecutive days responding to messages (maximum of 14 responses every 2 weeks). Payments were provided via reloadable debit cards.

Participants completed the Self-Care Inventory (SCI) (13), a 14-item self-report measure of self-care, at enrollment, 3 months, and 6 months and received $5, $10, and $15,

Corresponding author: Tara Kaushal, tara.kaushal@joslin.harvard.edu
https://doi.org/10.2337/ds21-0007

respectively, for each SCI completed. A1C levels were measured at routine clinic visits. The electronic health record system was used to extract these, as well as other clinical information such as concerns regarding depression, diabetes care plans, and BMI.

The MyDiaText website collected and stored data on daily text message responsiveness. For the purposes of analysis, we separated the group into low and high responders. Response rate (RR) was calculated by the number of text message responses divided by the number of days on study. The low responders were those answering ≤50% of the text messages over the 6-month study; high responders answered >50% of the text messages, similar to previous text messaging work in type 1 diabetes by McGill et al. (4). To understand engagement over time, we separated response rates in 6-day increments. Data from participants affected by a system malfunction causing two simultaneous text messages to be sent for a certain time period were removed from analysis, as receipt of two text messages daily—twice the intended amount—could potentially have led to reduced responsiveness.

Statistical analysis was performed using STATA software (Stata Corp., College Station, TX). Descriptive data are presented as mean ± SD unless otherwise indicated. Tests used included *t* tests, ANOVA, and χ^2. *P* values <0.05 were considered statistically significant. The study was originally powered to evaluate the impact of the intervention on self-care, and the current analysis is exploratory (10).

Results

Study Sample

A total of 83 participants received the incentivized text message intervention. No participants formally withdrew from study participation. Data from 29 participants from the days affected by the previously mentioned system malfunction were removed from the analysis; a median of 48 days of data were lost per participant.

Baseline Characteristics

Baseline characteristics are shown in Table 1. The mean age of the sample was 15.5 years, and the mean diabetes duration was 7 years. The sample was 46.3% male, 65.8% White, and 74% non-Hispanic. Mean BMI percentile was 74.1%, and 58.5% used an insulin pump or continuous glucose monitoring system. Mean baseline A1C was 9.8%, and mean SCI score was 3.1 out of 5.

Responsiveness to Text Messages

Over the 6-month study, 61% of participants were identified as high responders (*n* = 51) (Table 1). There were no significant differences in baseline characteristics between high and low responders in age, sex, diabetes duration, race, ethnicity, diabetes technology use, BMI, baseline SCI, baseline A1C, or clinical mental health concerns. There was a decline in RR over time for the overall sample and in both high- and low-responder groups (Figure 1). The mean RR for high responders was 87.2% in the first half of the study period and 69.0% in the second half, whereas the RR for low responders fell from 45.3% in the first half of the study to 6.1% in the second half (Table 1 and Figure 1). The decrease in RR by 6-day increments over the first half of the study and over the study overall was significantly greater in low responders (mean difference 72.3 ± 33.2% in the first half and 82.5 ± 27.2% throughout the entire study period) as compared with high responders (mean difference 13.3 ± 25.0% in the first half and 29.9 ± 38.2% throughout the entire study period; *P* <0.01 for both). Over the second half of the study, the decrease in RR was not significantly different, with low responders changing 9.3 ± 21.2% and high responders changing 22.6 ± 31.4%, (*P* = 0.07).

Glycemic Control

There was no statistically significant association between RR and change in A1C over the study period (*P* = 0.35). The difference in odds of improving A1C by ≥1% was not statistically significant between low and high responders (*P* = 0.18), which may have been related to the relatively small sample (type 2 error). However, the high responders were 2.1 times more likely to show improvement.

Discussion

This study demonstrated that, in adolescents with type 1 diabetes in suboptimal control, there was attrition of text message responsiveness over time, with low responders appearing to have a quicker drop-off in responsiveness than high responders. Responsiveness to motivational, educational, and supportive text messages as part of a financial incentive structure was not associated with glycemic benefit. RR was not correlated with sociodemographic or medical factors.

The overall RR and general drop-off in response over time were similar to those found in previous studies. Zhang et al. (5) found RRs over 8 weeks to be ~76%, which is not dissimilar to our finding of 71.1% over the first 3 months of the study. In the study by McGill et al. (4), participants were followed

TABLE 1 Results

Baseline Characteristic	Low Response Rate* (*n* = 32 [39%])	High Response Rate* (*n* = 51 [61%])	All Participants (*n* = 83 [100%])	*P*
Age, years	16.1 ± 2.0	15.6 ± 1.9	15.8 ± 1.9	0.27
Sex				0.70
Male	19 (59)	28 (55)	47	
Female	13 (41)	22 (43)	35	
Other	0 (0)	1 (2)	1	
Non-Hispanic White race/ethnicity	18 (56)	23 (45)	41 (49)	0.32
Diabetes duration, years	8.3 ± 4.5	6.6 ± 4	7.2 ± 4.2	0.10
A1C, %	10.4 ± 1.9	10.0 ± 1.8	10.1 ± 1.9	0.25
Mean SCI score (out of 5)	3.30 ± 0.56	3.48 ± 0.64	2.7 ± 1.5	0.47
BMI percentile	72.8 ± 25.8	74.6 ± 22.7	73.9 ± 23.8	0.99
Technology use				
Insulin pump	18 (56)	28 (55)	46 (55)	0.90
Continuous glucose monitoring system	20 (63)	34 (67)	54 (65)	0.70
Hybrid closed-loop system	2 (6)	3 (6)	5 (6)	0.95
Mental health care				
Clinical concern about depression	10 (31.3)	13 (25.5)	23 (28)	0.57
Receiving mental health treatment	6 (18.8)	11 (21.6)	17 (20)	0.76
Overall RR, %				–
Mean	29.3 ± 15.7	79.5 ± 15.6	58.6 ± 28.9	
First 90 days	45.3	87.2	71.1	
Second 90 Days	6.1	69.0	46.0	
Median	30.5	78.0	62.7	
Interquartile range	16.5–44.0	66.0–96.0	40.1–85.2	

Data are mean ± SD or *n* (%) unless otherwise noted. *Participants with a low response rate answered ≤50% of text messages, whereas those with a high response rate answered >50% of text messages.

three times longer than in this study; however, a similar decline in RR, from 60 to 43%, was found. Perhaps most striking about the drop-off rate of our study was the degree of difference between the high and low responders in the second versus the first half of the study. We hypothesize that drop-off stems from a waning over time of the initial motivation in response to text message contacts given the continued demands of diabetes self-care and other competing interests in the lives of adolescents with type 1 diabetes. Our data on the pattern of drop-off could be useful for future mobile health studies to understand such patterns in engagement and the motivations behind attrition.

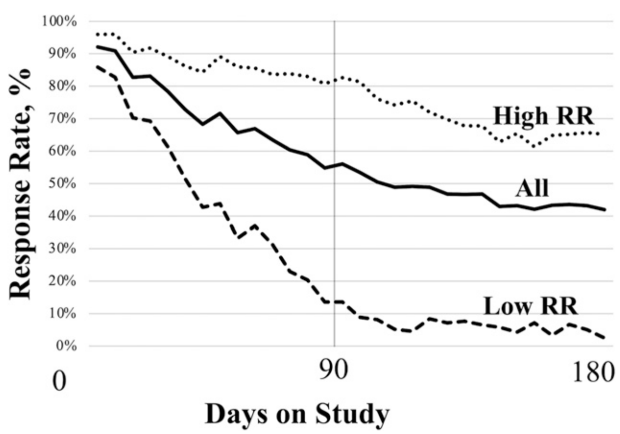

FIGURE 1 Mean RR over time as calculated in 6-day increments.

Sociodemographic and diabetes outcome–related baseline characteristics have been shown to correlate with engagement. McGill et al. (4) found that high responders were more likely to have greater frequency of blood glucose monitoring and lower A1C at baseline compared with low responders. Zhang et al. (5) found engagement to be greater in male and non-Hispanic White participants. A metanalysis of several digital behavior change interventions showed across multiple studies that engagement was negatively correlated with presence of mental health concerns and positively associated with female sex, increasing age, and higher education (14). In contrast, the baseline characteristics found in these studies did not correlate positively or negatively with RR in our sample. Mulvaney et al. (15) pointed out a lack of studies integrating extrinsic rewards into mobile interventions in diabetes. Perhaps the extrinsic financial reward component of this study caused a change in response patterns attenuating previously observed associations with various baseline characteristics.

Our study did have a few limitations. The technical malfunction caused some loss of data that may have caused our study to be underpowered. There was attrition in the completion of the SCI (10), limiting our ability to analyze potential associations between engagement and self-reported self-care. Mental health diagnoses were extracted from medical records and prone to subjectivity of clinician report and transcription error. Data on annual income and parental education levels were not available in our sample.

Despite these limitations, the observations from this study have the potential to inform further work. Future studies using extrinsic motivation to engage adolescents in a mobile intervention are needed, along with investigation of different motivational structures targeting at-risk adolescents with type 1 diabetes in suboptimal glycemic control. Alternatively, adolescents identified as low responders shortly after initiating a mobile intervention can be redirected to an alternative strategy to encourage engagement.

Conclusion

In adolescents with type 1 diabetes in suboptimal control, responsiveness to a psychoeducational and motivational text messaging intervention with financial incentives declined over time, with low responders appearing to have a more rapid drop-off in responsiveness than high responders. Responsiveness was not associated with glycemic benefit, nor was it correlated with sociodemographic or medical factors.

ACKNOWLEDGMENTS

The authors thank Janet Joseph, BA, and Michelle Marowitz, CRNP, and Daniel Atkins, BS, of CHOP; Knashawn H. Morales, ScD, of the University of Pennsylvania Perelman School of Medicine; Dean Ritter, BA, of FreedomPay, Inc.; and Reid Simon, BS, of the National Center for Advancing Translational Sciences.

FUNDING

The Community Engagement and Research Core in the Center for Health Behavior Research at the University of Pennsylvania is supported by the National Institutes of Health (NIH)/National Center for Advancing Translational Sciences Clinical and Translational Science Awards Program, award UL1TR001878. T.K. was supported by the NIH National Institute of Diabetes and Digestive and Kidney Diseases Pediatric Endocrinology Fellowship Training Award 2T32DK063688-CHOP. T.K. and L.M.B.L. are supported by NIH grants 5K12DK094721-09 and P30DK036836.

DUALITY OF INTEREST

No potential conflicts of interest relevant to this article were reported.

AUTHOR CONTRIBUTIONS

T.K. designed the study, performed the analysis, interpreted findings, and wrote the manuscript. T.H.L. designed the study, performed analysis, interpreted findings, and reviewed/edited the manuscript. L.E.L.K. designed the study, performed the analysis, interpreted findings, and reviewed/edited the manuscript. L.M.B.L. performed the analysis, interpreted findings, and wrote the manuscript. All authors read and approved the final manuscript. T.K. 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.

REFERENCES

1. Foster NC, Beck RW, Miller KM, et al. State of type 1 diabetes management and outcomes from the T1D Exchange in 2016–2018. Diabetes Technol Ther 2019;21:66–72
2. Borus JS, Laffel L. Adherence challenges in the management of type 1 diabetes in adolescents: prevention and intervention. Curr Opin Pediatr 2010;22:405–411
3. Anderson M, Jiang J. Teens, social media and technology 2018. Available from https://www.pewresearch.org/internet/2018/05/31/teens-social-media-technology-2018. Accessed 2 December 2018
4. McGill DE, Volkening LK, Butler DA, Wasserman RM, Anderson BJ, Laffel LM. Text-message responsiveness to blood glucose monitoring reminders is associated with HbA_{1c} benefit in teenagers with type 1 diabetes. Diabet Med 2019;36:600–605
5. Zhang S, Hamburger E, Kahanda S, Lyttle M, Williams R, Jaser SS. Engagement with a text-messaging intervention improves adherence in adolescents with type 1 diabetes: brief report. Diabetes Technol Ther 2018;20:386–389
6. Herbert L, Owen V, Pascarella L, Streisand R. Text message interventions for children and adolescents with type 1 diabetes: a systematic review. Diabetes Technol Ther 2013;15:362–370
7. Hanauer DA, Wentzell K, Laffel N, Laffel LM. Computerized Automated Reminder Diabetes System (CARDS): e-mail and SMS cell phone text messaging reminders to support diabetes management. Diabetes Technol Ther 2009;11:99–106
8. Petry NM, Cengiz E, Wagner JA, Weyman K, Tichy E, Tamborlane WV. Testing for rewards: a pilot study to improve type 1 diabetes management in adolescents. Diabetes Care 2015;38:1952–1954
9. Wong CA, Miller VA, Murphy K, et al. Effect of financial incentives on glucose monitoring adherence and glycemic control among adolescents and young adults with type 1 diabetes: a randomized clinical trial. JAMA Pediatr 2017;171:1176–1183
10. Kaushal T, Katz LEL, Joseph J, et al. A text messaging intervention with financial incentive for adolescents with type 1 diabetes. J Diabetes Sci Technol. Published online ahead of print on 30 August 2020 (doi: https://doi.org/10.1177/1932296820952786)
11. Kaushal T, Charmant CO, Volkening LK, Laffel LM, Katz M. Increasing heart-healthy behaviors in youth with type 1 diabetes (T1D): a feasibility study [Abstract]. Diabetes 2020; 69(Suppl. 1):165-LB
12. American Association of Diabetes Educators. AADE7 self-care behaviors for managing diabetes effectively. Available from https://www.diabeteseducator.org/living-with-diabetes/aade7-self-care-behaviors. Accessed 2 December 2018
13. La Greca AM. *Manual for the Self Care Inventory*. Available from https://people.miami.edu/_assets-profiles/acad-as/pdf/psychology/annette-lagreca-pdfs/sci-manual-2004.pdf. Accessed 13 December 2017
14. Perski O, Blandford A, West R, Michie S. Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. Transl Behav Med 2017;7:254–267
15. Mulvaney SA, Ritterband LM, Bosslet L. Mobile intervention design in diabetes: review and recommendations. Curr Diab Rep 2011;11:486–493