Development of a Text Message Platform to Enhance a Youth Diabetes Prevention Program: An observational process study.

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Abstract

Background: About 1 in 5 adolescents in the United States has prediabetes, and racial/ethnic minoritized youth are disproportionately impacted. Unfortunately, there are few effective youth diabetes prevention programs, and in-person interventions are challenging due to barriers in access and engagement.

Objective: We collaborated with our youth action board and a technology partner (mPulse Mobile) to develop a novel Short Message Service (SMS) based text-messaging tool to provide additional support and motivation to prediabetic youth participating in a virtual diabetes prevention workshop in East Harlem, NY.

Methods: The technology subcommittee of our Community Action Board (comprised of youth/young adults) used results from focus groups we had previously conducted with youth from our community to develop text message content. There are five message types focused on healthy eating and active living: goal setting, behavior tracking, individually tailored guidance, motivational messages, and photo diary. We conducted a pilot of the 12-week texting program with 13 prediabetic teens.

Results: Adolescents (ages 15-21, 77% female, 77% Hispanic/Latinx, 23% Black) received an average of two automated messages per day. The system correctly sent messages as intended 84% of the time. Level of engagement with the texting program ranged from 1 to 5 based on how frequently participants responded to interactive (2-way) messages. Highly responsive participants (46%) responded more than 75% of the time to interactive messages sent over 12 weeks, and 69% of participants were still engaged with the program at week 12. During a focus group conducted after program completion, teens remarked that the message frequency was appropriate, and those who had participated in our in-person workshops reflected that the messages were reminiscent of the workshop content. Participants rated goal setting, behavior tracking, and tailored messages most highly and informed planned adaptations to the platform. Participants described the program as: “Interactive, helpful, informative, enjoyable, very convenient, reliable, motivational, thoughtful, productive, and reflective.”

Conclusions: We partnered with youth in the initial content development and pilot testing of a novel text-messaging platform to support diabetes prevention. This study is also unique in its triple partnership between academia, technology experts, and youth to develop an mHealth platform to address diabetes-related disparities.

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Development of a Text Message Platform to Enhance a Youth Diabetes Prevention Program: An observational process study.

Abstract

Background: About 1 in 5 adolescents in the United States has prediabetes, and racially and ethnically minoritized youth are disproportionately impacted. Unfortunately, there are few effective youth diabetes prevention programs, and in-person interventions are challenging due to barriers in access and engagement.

Objective: We aimed to develop and assess the preliminary feasibility and acceptability of a youth-informed text messaging program to provide additional support and motivation to adolescents with prediabetes participating in a diabetes prevention workshop in East Harlem, NY. We collaborated with our youth action board and a technology partner (mPulse Mobile) to develop and pilot test a novel interactive Short Message Service (SMS) based text-messaging platform.

Methods: The technology subcommittee of our Community Action Board (comprised of youth/young adults) used results from focus groups we had previously conducted with youth from our community to develop text message content. There are five message types focused on healthy eating and active living: goal setting, behavior tracking, individually tailored guidance, motivational messages, and photo diary. We used an iterative process to first develop and pilot the program with our internal study team including youth from our Community Action Board and mPulse developers. We then conducted a pilot of the 12-week texting program with 13 teens with prediabetes.

Results: Participants (ages 15-21, 77% female, 77% Hispanic/Latinx, 23% Black) received an average of two automated messages per day. The system correctly sent messages as intended 84% of the time.; the remaining 16% of messages were either sent at the incorrect time or the system did not recognize a participant response to give the appropriate reply. Level of engagement with the texting program ranged from 1 to 5 based on how frequently participants responded to interactive (2-way) messages. Highly responsive participants (46%) responded more than 75% of the time to interactive messages sent over 12 weeks, and 69% of participants were still engaged with the program at week 12. During a focus group conducted after program completion, teens remarked that the message frequency was appropriate, and those who had participated in our in-person workshops reflected that the messages were reminiscent of the workshop content. Participants rated goal setting, behavior tracking, and tailored messages most highly and informed planned adaptations to the platform. Participants described the program as: “Interactive, helpful, informative, enjoyable, very convenient, reliable, motivational, thoughtful, productive, and reflective.”

Conclusions: We partnered with youth in the initial content development and pilot testing of a novel text-messaging platform to support diabetes prevention. This study is unique in the triple partnership we formed among researchers, technology experts, and diverse youth to develop an mHealth platform to address diabetes-related disparities.

Keywords: Community-based Participatory Research; youth; diabetes prevention; peer education; mobile health technology; text messaging

Introduction

The rise in the prevalence of type 2 diabetes (DM) and prediabetes (a condition in which glucose levels are higher than normal but not high enough to diagnose diabetes) among youth has been widely reported as a growing epidemic. In the US, about 1 in 5 adolescents has prediabetes [1]. A 2016 consensus report by the American Diabetes Association highlighted racial/ethnic disparities in youth-onset type 2 diabetes with a prevalence four times higher among Hispanic/Latinx youth and five times higher among Black youth than among their non-Hispanic white peers [2]. There is evidence that youth-onset DM progresses more quickly and results in earlier complications compared to adult-onset DM [2]. However, it is promising that lifestyle interventions have proven effective in preventing or reversing the progression of prediabetes to DM. A large randomized controlled trial in adults showed that a lifestyle intervention was twice as effective as glucose-lowering medications in preventing diabetes among high-risk adults [3]. Another study found that obese adolescents who maintained their weight and BMI were more likely to revert from impaired to normal glucose tolerance compared to those who gained weight [4].

Unfortunately, there are few effective prevention programs for the racially/ethnically minoritized youth who are disproportionately impacted by this disease [5, 6]. The population in our community (Harlem in New York City) is largely Hispanic/Latinx and Black. Almost half of all school-age children and a third of high school students living in this community are overweight or obese [7, 8]. Given the strong association between obesity and prediabetes among adolescents [1], there is a pressing need for effective diabetes screening and prevention programs in communities like ours. To address this gap, we developed TEEN HEED (**H**elp **E**ducate to **E**liminate **D**iabetes), a 12-week peer-led diabetes prevention intervention aimed at improving lifestyle and metabolic risk factors among youth with prediabetes. We developed this intervention using community-based participatory research (CBPR), a collaborative approach that incorporates the values of both community and academic stakeholders in the research process [9]. Our preliminary results showed that most adolescents who completed >50% of the program no longer had prediabetes at 3 month follow up and that workshop participants had an improvement in physical activity self-efficacy and health behaviors such as portion control [10].

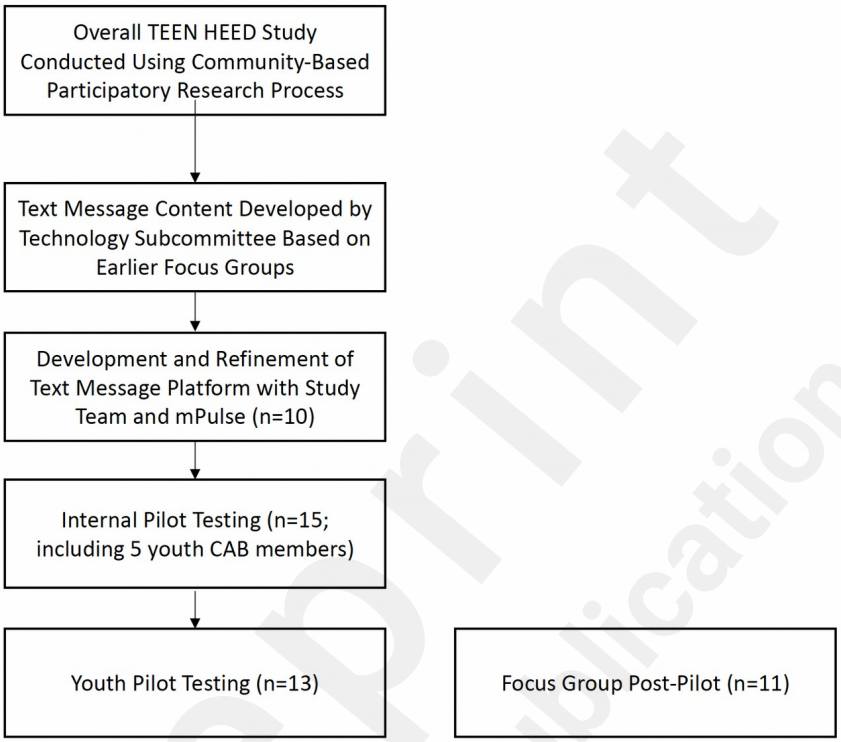
Despite these promising results, it remains a challenge to impact youth through in-person interventions due to barriers in access and engagement [11]. One potential solution is to deliver interventions via virtual platforms in order to reach more youth and address logistical barriers such as scheduling, transportation, and competing priorities [11]. The Pew Research Center reported that smartphone access among teens in the US increased dramatically from 73% in 2014-2015 to 95% in 2018 [12, 13]. Smartphone ownership is almost ubiquitous among teens, regardless of gender, race/ethnicity, or socioeconomic background [12]. In fact, teens from lower income households are more likely to use their phone to access social networks and health information than those from higher income households [12]. Thus, mobile health (mHealth) interventions are even more promising among adolescents who are most at-risk and who also face socioeconomic barriers affecting access to prevention programs.

In this study, our aim was to develop a mobile health text messaging intervention as a potential avenue to broaden the impact of TEEN HEED. To do this, we partnered with mPulse Mobile, a mobile health tech company, in addition to our youth action board, to develop a novel Short Message Service (SMS) based text messaging tool to support diabetes prevention efforts targeting youth with prediabetes in East Harlem. In this manuscript, we present the participatory process we used in collaboration with youth and technology partners to iteratively develop and refine the texting program and examine feasibility and acceptability data from early pilot and usability testing.

Methods

Please see the consort flow diagram which summarizes the various phases of the study (Figure 1) which are described in more detail below.

Figure 1: Consort Flow Diagram



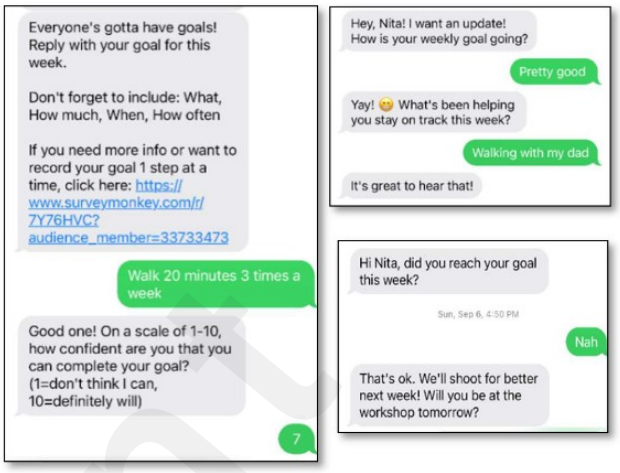
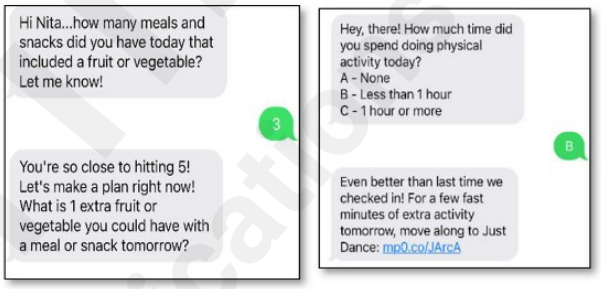
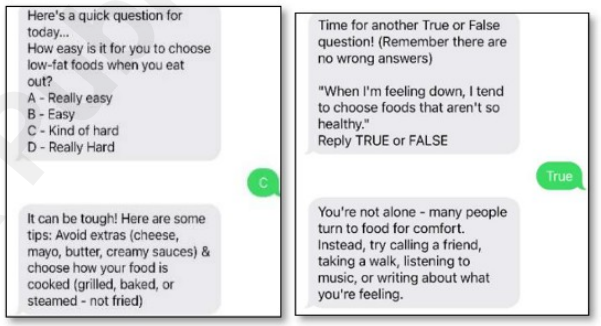
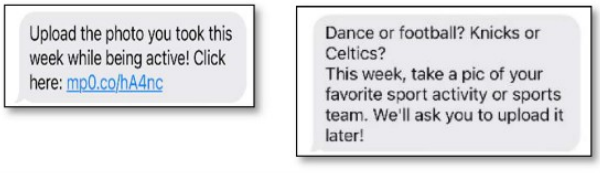
Preliminary Studies

As a first step to better understanding the feasibility of a mobile health lifestyle intervention for youth in the East Harlem community, we conducted six focus groups with more than 50 young people recruited through our community partners [10]. We examined social and environmental factors that may impact lifestyle, barriers to healthy behaviors, and ways in which mHealth may be used as part of diabetes prevention efforts. Most teens in our focus groups preferred text messaging over social media and mobile health apps to deliver healthy lifestyle content [10]. Teens cited the opportunity to personalize text messages and the convenience of not having to log on to another platform as reasons for preferring text messaging over other mHealth modalities [10]. Participants discussed which types of messages would resonate best with adolescents and how to present messages to maximize engagement. Adolescents suggested that messages promoting goal setting and self-monitoring of behaviors and tailored content based on user characteristics and reported behaviors would allow for more participant engagement [10].

The CBPR Process

The CBPR approach we used for the TEEN HEED study involved development of each aspect of the project with members of our Community Action Board (CAB), including youth. For the mHealth component, we aimed to develop a text message platform that would engage teens throughout the week and coincide with content from the weekly workshop sessions. Youth members of our CAB's Technology Subcommittee (ages 16 to 22) used the results of focus groups conducted at an earlier time and published separately, to brainstorm message types and frequency and to draft content [14]. We iteratively developed messages with clarification of content queried by email and phone to gather further youth feedback. Their input contributed to the language used in automated text message prompts and system responses including words of positive reinforcement and motivational graphics/images. We collaboratively developed five categories of messages and created a spreadsheet with weekly messages including day/time of message delivery and automated responses to messages received (see Table 1 for descriptions and examples of each message type). Goal setting messages prompt teens to enter a weekly goal, report their progress mid-week and report whether they completed their goal at the end of the week. Repeated behavior tracking messages focus on key dietary behaviors (fruit/vegetable and sugary drink intake) and physical activity behaviors (moderate to vigorous physical activity and screen time). Workshop specific messages focus on behaviors covered in the session that week (e.g., label reading, plate planning, and incorporating activity into daily routines). Tailored messages ask participants questions about their habits with individualized feedback/guidance given based on their responses. Motivational messages are inspirational quotes or graphics. Finally, photo diary messages ask participants to 'snap-a-pic' of different things related to healthy lifestyle to upload later in the week.

Table 1. Message type description and examples

Message Type	Description	Example
Goal Setting	Teens are prompted to enter a weekly goal, check in about progress, and report on goal completion.	
Behavior Tracking	Participants report on behaviors (e.g., reading nutrition labels) and record key behaviors over time (fruit and vegetable intake, screen time, physical activity, and servings of sugary beverages) with weekly individualized feedback.	
Tailored	Participants receive automated messages with feedback based on responses to questions.	
Motivational	Inspirational quotes and links to motivational graphics with text.	
Photo Diary	Teens are prompted to upload images pertaining to healthy eating and active living.	

mPulse Mobile Platform

We developed an SMS (Short Message Service) based text messaging program with our partner technology company mPulse Mobile (HITRUST Common Security Framework/HIPAA certified). User profiles are entered into the system with basic demographic information. The "About" section of the participant's profile is updated based on weekly responses to message prompts. We programmed message content developed by our CAB's Technology subcommittee into workflows on the mPulse platform, which is based on interactive dialogues (automated rule-based branching logic that allows users to navigate through the program based on their message responses). We collaboratively and iteratively refined how the youth-developed content was programmed through weekly meetings. Some early refinements included adding no response reminders to goal setting and behavior tracking dialogues, reordering messages so that participants receive an average of two messages per day, balancing interactive and 1-way messages, streamlining the goal setting prompt 4 weeks into the program, adding workflows for a more interactive experience, and modifying messages for teens who did not attend workshop sessions. An innovative program feature is artificial intelligence/natural language understanding (real-time interpretation of text responses that enables more sophisticated dialogues and solution-specific conversational agent capabilities). Beyond processing the responses that move users through automated dialogues, natural language understanding and a library of automatic replies handle user responses that fall outside the scope of the dialogue's rules. An Engagement Console allows research staff to manage individual interactions with participants. The Console identifies responses that cannot be handled by the messaging program's rules, allows staff to manually initiate messages, and flags high-priority messages for escalation in real-time for review and response by project staff.

Internal Pilot Testing

After development of the prototype, we conducted an internal pilot with 13 testers - the PI, the research coordinator, members of our CAB Technology Subcommittee, and mPulse team members. We held weekly meetings to discuss what was working and suggest improvements. After testing the content from Weeks 1 and 2, we decided to decrease the message frequency by reducing the number of behavior tracking messages from four to two per week and alternating dietary and physical activity questions so that each question would be asked every other week. We also reduced the motivational and "Snap a Pic" messages from two to one time per week. Once our program developer made these changes, the internal pilot restarted from week 1 to evaluate these changes. Additional changes made during internal pilot testing included limiting morning messages to non-interactive dialogues, introducing a "Helper Bot" to automate responses when the system did not understand a user's response, removing photo upload messages that included user's faces to maintain anonymity, adding a motivational message halfway through the program, changing links that did not work, a global rule for "Not sure" or "Don't know" responses, and adjusting message timing.

Pilot Testing with Youth

We next invited youth from our pediatric clinic and the East Harlem community ages 13-21 who had previously participated in the TEEN HEED study to pilot the text messaging program. The study coordinator individually contacted 26 previously enrolled study participants by phone and email to gauge interest in pilot testing the texting program. Ultimately, 13 teens consented (9 who had been randomized to the intervention group and previously attended our in-person workshops and 4 who had been randomized to the control group and had not attended the workshops). Teens participated in the 12-week pilot from August - November 2020. Participants received two system automated messages per day at 9am, 3pm, 6pm, or 9pm (timings varied based on message type). Timing of messages was intentional as we discussed when youth were more likely to be available to respond to interactive messages and when different messages were most relevant (e.g., adolescents were most likely to be tempted or challenged with unhealthy behaviors after school and to reflect on their behaviors at the end of the day). In order to obtain additional information about message content and optimal message frequency, we decreased the number of messages sent in weeks 8-11 and included some repeat messages from previous weeks. In week 12, teens received a final congratulatory message for completing the program. At the end of the 12 weeks, the teens participated in a focus group via Zoom during which we asked about general system feedback, message frequency, message types and content, and suggestions for improvement.

Data Collection and Analysis

Participant engagement data was collected by the text messaging platform and viewable in the mPulse engagement console. The text messages often asked questions or prompted users to reply. For example, a goal setting prompt of “would you like to set a goal today?” would expect a response. The platform would “listen” for these responses and followup with an automated message in real time using rules and natural language processing. Every message sent and received by the system was timestamped and saved in the platform and linked to a participant’s unique ID. In addition to automated messages generated by the platform, the engagement console was occasionally used to reply to participants directly with more personal and non-automated messages. If a participant replied to a 2-way interactive text message, they were considered to have engaged and if they did not reply to a 2-way interactive text message they were considered to have not engaged. If they replied “stop” to opt out they were considered to have opted out. Participant demographics were collected via self-administered surveys. All quantitative data from texting outreach and participant demographics were analyzed using R and Excel, and data visualization was conducted using Tableau. We analyzed qualitative data from the focus group using notes from the moderator and verbatim transcription of participant quotes from the focus group audio recording. We used open coding and thematic analysis to identify key themes which will inform planned program adaptations.

Ethical Considerations

This study was approved by the Institutional Review Board at the Icahn School of Medicine at Mount Sinai (STUDY-14-00359). We obtained informed consent from adolescents ≥18 years and from parents/caregivers for adolescents <18 years. No compensation was provided to study

participants for this portion of the study. Study data were de-identified to protect participant privacy and confidentiality. Study data was secured on password protected Mount Sinai servers.

Results

Participants

Descriptive statistics for the youth who participated in the text messaging pilot are presented in Table 2. Participants ranged from 15-21 years (M = 18.54, SD = 1.87) and most (77%) identified as female. In terms of race/ethnicity, 77% of participants identified as Hispanic/Latinx and 23% identified as Black. 54% of participants had parents who were born outside the United States. Of those who had previously participated in the in-person workshop, two had attended <4 sessions, three had attended 5-8 sessions, and four had attended 9-12 sessions.

We ranked participants based on level of engagement (responsiveness to 2-way interactive messages) with 15% responding 0-10% of the time, 31% responding 25-50% of the time, and 46% responding greater than 75% of the time over the 12 weeks. We analyzed responses from users to text messages about their typical diet and physical activity behaviors. Of those who answered the messages, most participants (4/6) stated that they found it hard to choose low-fat foods when they ate out; all (7/7) usually order a medium size fast food meal; most (6/7) reported that they at times eat a bigger portion than what they need; most (7/8) enjoyed drinking water, most (8/9) did not drink juice with their breakfast; and most (5/7) reported that they tend to choose unhealthy foods when they are feeling down. When asked about physical activity, 4/6 stated that they get some activity but could do more. Most (6/7) agreed that it was important for them to look their best (value appearance).

Table 2. Descriptive Statistics

	Demographics	**Number (%)**
Gender		
	Male	3 (23%)
	Female	10 (77%)
Race		
	Hispanic/Latino	10 (77%)
	Black/African-American	3 (23%)
Type of Hispanic/Latino		
	Puerto Rican	4 (40%)
	Mexican	3 (30%)
	Honduran	2 (20%)
	Ecuadorian	1 (10%)
Parent Place of Birth		
	Ecuador	1 (8%)
	Mexico	3 (23%)
	Puerto Rico	1 (8%)
	Honduras	2 (15%)
	United States	5 (38%)
	Caribbean	1 (8%)
In-person Workshop Group		

	Intervention	9 (69%)
	Control	4 (31%)
Session Attendance for Intervention Group		
	0-4	2 (22.2%)
	5-8	3 (33.3%)
	9-12	4 (44.4%)
Virtual TEEN HEED Activity		
	1 – Little to no response	2 (15%)
	2	0
	3 – Somewhat responsive	4 (31%)
	4	1 (8%)
	5 – Highly responsive	6 (46%)

Message Delivery and Level of Engagement

When tracking the fidelity of message delivery, 84% of messages were sent correctly (on the expected date and time). To address any errors in message delivery, we tracked the messages in the Engagement Console and manually sent any messages that were either not sent or sent incorrectly. Over the 12-weeks of the pilot program, 11 out of the 13 teenagers who consented to participate in the study (85%) were responsive to interactive 2-way messages with 69% of participants still engaged with the program at week 12 (Figure 2). The number of interactive messages sent and received were recorded monthly and are presented in Table 3. Messages were labeled as 2-way or interactive if they ended in a question mark and a response was expected. Response rates to interactive messages started at almost 60% in the first month and decreased to about 30% toward the end of the program when teens received fewer messages from the system. The system received an average of 77 messages per week (7 messages per active user per week) over the first 7 weeks of the program and an average of 47 messages per week (about 4 messages per active user per week) in weeks 8-12 when we reduced the number of weekly messages sent.

Figure 2. Engaged members by week

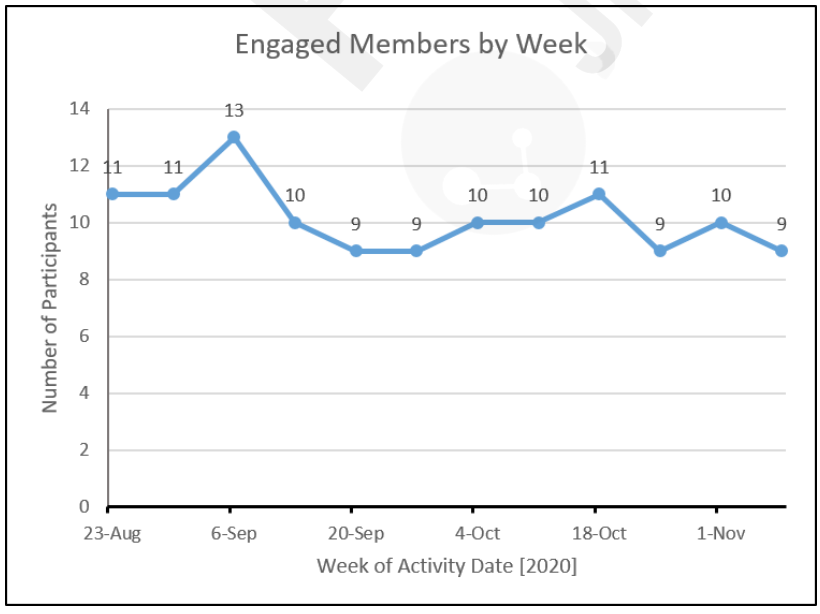


Table 3: Participant interaction with message-types sent

Messages sent by type (2-way interactive vs. 1-way)							
August		**September**		**October**		**November**	
2-way	1-way	2-way	1-way	2-way	1-way	2-way	1-way
134	97	603	551	603	396	198	74
Monthly Engagement rate for 2-way Interactive messages (messages received/messages sent)							
56.7%		39.8%		31.5%		27.3%	
76/134		240/603		190/603		54/198	

Additionally, we originally programmed the system to send a response to any messages received (either a programmed response, an emoji, an encouraging statement, or in the case that the system could not understand a response, a variation of, “Sorry, but I'm just a bot so I don't have a clever response. 😊 Remember, you can reach out to Dr. Nita directly if you need!”). While tracking messages in the Engagement Console, we noticed that some users engaged less with the system after receiving multiple bot messages. As a result, we opted to remove the bot messages after week 5 and instead had the project coordinator monitor the console and manually respond to participants when necessary.

Focus Group Findings and Planned Adaptations

In addition to tracking the Engagement Console and user analytics as described above, we conducted a focus group with 11 participants after the 12-week program to further examine user feedback about message timing, frequency, type, and content. We asked participants to choose individual words to describe the program and responses included “Interactive, helpful, informative, comforting, enjoyable, convenient, reliable, motivational, thoughtful, healthy, productive, and reflective” When asked about the number of messages, participants remarked that the messages “were not intruding...considering that the program is only through messages, I think the frequency of the messages is necessary, so that [participants] feel the presence - that the program is there…”. When the messages were reduced after week 7, participants reported that they noticed the decrease in frequency, felt that the program was coming to a close, and missed the additional messages. Those who had also participated in our in-person workshops mentioned that the text messages were reminiscent of the in-person workshop content. Overall, participants enjoyed goal setting, behavior tracking, and personalized messages the most. With busy school and work schedules, participants appreciated receiving multiple messages to review their goals and track their progress each week. They suggested that messages could be further tailored based on their user profile and personal habits/goals. A summary of relevant quotes and planned program adaptations informed by focus group findings are presented in Table 4.

Discussion

Principal Findings

Our text messaging program was well received by participants based on both analytics and qualitative feedback. At least 9 of 13 participants who initially consented to the study were engaged each week throughout the 12 weeks. In addition, we received 50-75 messages per week across the 13 users (a range of 4-8 messages received per user per week). Of note, we had high engagement rates despite having a higher dose of messages delivered weekly than other similar programs [15]. A systematic review of text messaging interventions for weight management in adolescents found a

median of 1.5 text messages sent per week across the studies (range 1-21 text messages), with half of the interventions including delivery of messages only once per week or once per month [15]. In contrast, we sent an average of two messages per day. Jensen et al found that most participants would prefer fewer messages [16], but our participants seemed to miss the high volume of text messages once the dose decreased in later weeks. One reason for this may have been the incorporation of messages focused on goal setting, behavior tracking, and tailored guidance, which our participants favored based on our focus group findings, and which might have increased the relevance and perceived value of the messaging.

Comparison with Prior Work

Among youth mHealth lifestyle interventions, text messaging has been shown to be more acceptable and effective as an intervention delivery method compared to mobile health apps and social media [15, 17]. A recent systematic review of the effectiveness of text messaging interventions for weight management in adolescents found that 7 of the 8 identified studies demonstrated a decrease in BMI or BMI z-score in the intervention group compared to the control group [15]. A 2012 Pew research survey showed texting by far to be the most common daily form of communication used by teens, even at a time when only 77% of teens reported having a cell phone [18]. These results align with what we learned from our prior focus groups with youth, in which most teens preferred text messaging as the delivery method to support our diabetes prevention program [14]. Teens preferred text messaging over social media and mobile health apps due to the ease of not having to log into a separate platform and stated that they would be more likely to respond to a text message than to a notification via Facebook or an app [14]. Given the strong evidence supporting text messaging as a modality for delivering lifestyle interventions among youth, as well as the specific support for this strategy from teens in our own focus groups, we chose to deliver our intervention through text messaging.

While there are examples of effective text message-based lifestyle intervention studies in youth, our study addressed multiple gaps in the literature [19-21] First, there is limited information about the most effective message content and timing [15, 22-26] In a systematic review of the effectiveness of text messaging interventions for weight management in adolescents, Partridge et al found that although most teens said they preferred more personalized messages, only half of text messaging interventions for weight management in adolescents included features such as two-way texting or personalized messages [15]. The systematic review also found that adolescents who received interventions that incorporated two-way interactive messages had better engagement compared to those in control groups and gained more knowledge than those who received one-way messages. Newer technologies such as artificial intelligence and natural language processing that have the ability to personalize text messages and engage users in two-way dialogues are only now starting to be incorporated into text messaging programs [16, 27-32] We were able to harness the potential of these new features and technologies through our partnership with mPulse Mobile.

Another important aspect of our study that distinguishes it from prior studies is the level of involvement of youth as members of our study team throughout the process. Some studies have incorporated youth feedback through participation in focus groups or surveys after development of text messaging interventions. For example, Jensen et al tested text messages in a 3 month feasibility study by using surveys and semi-structured interviews to garner feedback about message content and timing [16]. Two other studies sought youth perspectives on mobile health apps used for lifestyle interventions in obese youth without building an actual app [25, 33]. Another study had an advisory team with 4 adolescents who gave formative feedback on content and delivery modality for their mobile health intervention, and youth who participated in the subsequent RCT gave feedback

through a six item multiple choice questionnaire [20]. However, none of these studies involved youth as equal stakeholders throughout the development process [20, 34, 35]. The few prior studies that used more participatory approaches to develop message content for adolescents resulted in high engagement and acceptability [15]. In alignment with these studies, we partnered with local teens who were deeply involved in the development, testing and evaluation of our program.

Triple Partnership: Youth, Technology, and Academia

In addition, few mHealth studies have included diverse stakeholders including academic researchers, technology experts, and members of the target population. To our knowledge no prior studies have leveraged the type of unique three-way partnership we built to develop an mHealth lifestyle intervention for youth. Through our partnership with the youth on our CAB and mPulse Mobile, we are the first team to implement such a collaboration. Some previously cited reasons for the lack of academic-industry partnerships are "(1) (for the academic) striking the "right" balance between cultivating a relationship with industry partners while navigating the practical considerations and constraints of academic appointments; (2) agreeing on ambitious but feasible timelines and deliverables to meet industry demands; and (3) selecting appropriate outcome and evaluation metrics that stand up to the rigor of academic research while remaining responsive to market-values and industry priorities." [36]. For our study, it was important to find a technology partner who was not primarily motivated by how financially lucrative the developed platform would be so that we could first focus on developing the program collaboratively with our youth partners to make it appealing to our target population. The philanthropic nature of our initial collaboration has been the foundation for us to develop a mutually beneficial relationship, as industry helps the community, the community informs industry, and we are able to use our expertise as researchers to evaluate and disseminate our work. In this way each group can share their insights and benefit from knowledge gained.

Strengths and Limitations

Strengths of this study include the use of CBPR methods with deep involvement of youth from our community in the creation and pilot testing of our text messaging program. This novel program uses AI and natural language understanding features to provide tailored two-way messages. This study is also unique in its triple partnership between academia, program developers, and minority youth to address disparities in obesity and diabetes rates.

Limitations of the study include the small sample size for pilot testing our program. Other studies that tested a text messaging lifestyle intervention among youth had a wide range of sample sizes, from 14 to 47 participants [16, 20, 30, 37]. Our findings are specific to the small group of youth we collaborated with to develop and pilot our program and should not be generalized to youth from populations that are significantly different from ours. Although our study included more female and Hispanic youth, we could not examine trends in these subgroups due to the small sample size but plan to explore subgroup differences in future studies. Our study was conducted during the summer of 2020 at the height of the COVID-19 pandemic in New York City. This may have influenced the engagement of adolescents. In addition, our participants included teens who were highly engaged in the original TEEN HEED study and had strong relationships with the study team. Thus, the high engagement rates we observed may not be representative of what would be observed among larger groups of teens. We also had some unforeseen technical issues and limitations in the types of messages we could send. For example, we could not include text messages with embedded images so our motivational messages instead had to focus on inspirational quotes and web links to images. Despite these limitations, teens still enjoyed these messages.

Conclusion and Future Directions

Our process, feasibility, and acceptability study informed several strategies to improve the text message program for future iterations of TEEN HEED as summarized in our Planned Adaptations table. One such adaptation is implementing a hybridized model between human and autogenerated messages. One study in which all text message reminders sent to participants were human-generated reported response rates of 70-80% [38]. In our study as well, we noted that participants responded more positively to messages sent manually by the project coordinator than the bot generated error messages. Though human-generated messages require additional time and labor, the possibility for increased engagement suggests that a hybridized model may be useful to increase engagement while remaining feasible. This will require more effort to implement, but we plan to prioritize certain participants and situations for this type of direct human interaction (e.g., participants with low response rates, those who are not meeting their goals, or those who request additional support). In addition, youth suggested that the ability to share the experience with other youth would be helpful. This could be incorporated by sharing the photo journal upload results in a common space to create a sense of community. Other youth mHealth studies have focused on peer support to increase acceptability and engagement [34]. Friendly competitions and creating ways to share group accomplishments is another way to increase social interactivity and engagement. Lastly, in the next iteration of TEEN HEED we plan to maintain the same message frequency throughout the program and to further customize messages based on user profiles and trends in reported behaviors over time.

We hope that the results from this study can inform future text messaging programs targeting youth to address health disparities.

Table 4. Planned Adaptations to Text Message Platform

Findings from Pilot Testing	Planned Adaptations to Platform
Message Frequency "You felt like the program was coming to an end once the messages started coming less frequently. It was a little sad since I was doing it since school started so it was part of my routine."	Maintenance of same message frequency throughout program with less frequent messages only after workshop completion (an average of two daily messages in the first 12 weeks followed by an automated weekly maintenance message and additional manually initiated messages through 12-month follow-up).
Tailored Messages "It served to remind me of the things I could be doing…These types were the best for me when I was very busy because they were very quick…they're simple, short, quick facts." "If it was a little more interactive, I would have benefitted more from it, instead of responding and forgetting about it."	Personalization of messages using data entered when creating user profile (personal characteristics, habits, and goals). Increase interactivity with more two-way exchanges and detail in dialogues.
Goal Setting "I think they were great. I just wish they were more repeated at the date and time that I chose to set my goal for."	Use natural language understanding and peer leader messaging through the engagement console for personalization of goal reminders.

"Maybe [the system should] ask "what troubles did you have?" and then after you respond it should follow up with "would you like to talk with a peer mentor?"– if you say yes, it will schedule one, and if you say no you can continue on with your day."	Hybridization of automated messaging and human interactions to trouble shoot challenges with goal completion.
Behavior Tracking "The frequency, the variety of these types of messages are good as is. I got a link to Just Dance, but I have to be honest I didn't press on the link mainly because of the timing of those messages. I think it was always while I was on the bus coming home from work and the last thing I really wanted to do was watch a video."	Personalization of messages using data entered when creating user profile (personal characteristics, habits, and goals). Customization of message timing based on user schedules.
Workshop Specific Messages "I agree that the messages of my plate reminded me of activities from the actual program." "Because they were short, I liked them. They did remind me of the workshop. These are good for small reflections."	Increase frequency of messages reflecting workshop content.
Motivational Messages "I liked a good amount of the linked ones…but the quotes were just better and easier than the linked ones."	Increase focus on inspirational quotations for motivation instead of links to graphics.
Photo Diary "I thought it was going to be a more collaborative thing when we sent the photos. Without that it feels like we're sending the photos for nothing."	Create a shared space for photos to increase interactions between participants.
I'm Just a Bot Messages "I knew it was bound to happen because it's a bot with automated messages. But I just tried to stop myself from saying random things because the bot doesn't understand."	Remove "I'm Just a Bot. I don't understand." messages, refine artificial intelligence and natural language understanding capabilities, and monitor engagement console for instances when system cannot handle messages.
Peer Leader Initiated Messages "I noticed a difference in my response to Cordelia's personal messages–I thought "oh it's a human, so I can actually respond and a person's going to read it right then and there and possibly respond. So I made a more lengthy response – something more meaningful."	Increase hybridization of automated messages and peer leader-initiated messages for increased engagement.
Additional Suggestions Quick stats, facts, and tips Short quizzes Group competitions Visual content	Addition of brief messages focused on diabetes statistics, facts, tips, and quizzes about workshop content. Increase social interaction with friendly competitions (step challenges, etc.).

	Share group accomplishments visually and incorporate visual story telling message content.

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Data Availability: The data sets generated and analyzed during this study are not publicly available due to the small sample size and potential for our participants to be identified. However, the data set is available from the corresponding author on request.

Conflicts of Interest: None declared

Abbreviations:

CAB: Community action board
CBPR: Community-based Participatory Research
TEEN HEED: Teens Help Educate to Eliminate Diabetes

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Supplementary Files

Figures

Consort Flow Diagram.