Research and Applications

Engaging users in the design of an mHealth, text message-based intervention to increase physical activity at a safety-net health care system

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ABSTRACT

Objectives: Text-messaging interventions are a promising approach to increasing physical activity in vulnerable populations. To better inform the development of a text-messaging intervention, we sought to identify barriers and facilitators to using text messaging and engaging in physical activity among patients with diabetes and co-morbid depression.

Materials and Methods: We conducted interviews with primary care patients at a safety-net health care system ($N = 26$). Data were collected at 3 stages, including a focus group (stage 1), and individual interviews (stage 2 and 3). Patients in stage 1 and 2 previously participated in a text-messaging intervention as part of depression treatment. Discussions focused on participant experience of previously using a text-messaging intervention, influences and perceptions of physical activity, and mobile phone use. We analyzed all transcripts for emerging themes.

Results: Participants were 56.2 years (± 9.7); 69.2% were female, 65.4% identified as Hispanic/Latino(a), and 46.2% reported having less than a high school education. All had depression and 61.5% had diabetes. Specific barriers that emerged included low literacy and only basic use of mobile phones in everyday life, in combination with a high prevalence of comorbid health conditions and limited mobility. These were each addressed with a specific content or intervention delivery change in the overall intervention design.

Conclusions: Conducting a focus group and individual interviews with end users of an mHealth intervention under development has implications for tailoring and modifying components of the content and format to ensure that the final intervention will engage end users most effectively.

Key words: mobile health, text messaging, physical activity, diabetes, depression

INTRODUCTION

Diabetes and depression are highly comorbid disorders among low-income populations.[1] In patients with diabetes, depression is associated with increased mortality.[2] Among patients with type 2 diabetes, higher levels of physical activity has been correlated with lower levels of perceived stress, depression, and anxiety.[3] However, the comorbidity of both depression and diabetes is associated with poorer self-management, resulting in less physical activity engagement.[4]

Mobile health (mHealth) interventions, such as those involving text messaging, have been effective in improving glycemic control for diabetes and increasing physical activity.[5–10] However, vulnerable, or underserved populations including low-income, racially, and ethnically diverse patients with diabetes and/or depression experience additional barriers to engaging in regular physical activity.[11–15]

As mHealth interventions for diabetes and depression are developed, it is crucial to understand and address the needs and barriers to increasing physical activity among vulnerable populations to better engage the end users of such interventions. Despite concerns regarding lower digital and health literacy, previous studies have found high rates (94%) of smartphone ownership in this population.[16] Although there are a few studies that have successfully developed digital interventions to increase physical activity among diverse patients,[17–19] there is little published on the design process of implementing such interventions or their use in clinical practice. This demonstrates an unmet need for engaging end users early in the design process.[20–22] More specifically, effective interventions will combine content adaptation with tailored intervention delivery processes with direct feedback from diverse end users.

Recognizing the importance of engaging end users in early stages of the design process, we utilized a user-centered design framework (UCD) to inform content and intervention delivery considerations for developing text message based physical activity intervention, the Diabetes and Mental Health Adaptive Notification Tracking and Evaluation trial (DIAMANTE; NCT03490253), that has yet to be evaluated. This intervention aims to utilize an app collecting step counts and a machine learning algorithm to send personalized messages to increase physical activity among patients with diabetes and depression. Theoretical frameworks of UCD include evidence-based approaches that centralize understanding the profile of end users (patients) to ensure that the mHealth interventions are applicable and accessible to the target population.[23] The purpose of this article is to identify the general barriers and facilitators for using text messaging and engagement in physical activity in Spanish and English speaking patients with diabetes, comorbid depression, and low-physical activity engagement. Findings from this multi-staged study will be used to inform content and information delivery decisions in the final DIAMANTE intervention including selecting the thematic message categories, and design requirements.

MATERIALS AND METHODS

Study design, sample and participant recruitment
This multi-method qualitative study was carried out in safety-net health care hospital between 2016 and 2018. Providers in safety-net health care systems are mandated by legal obligation or mission statements to provide access to health care regardless of a patient's insurance status.[24] A total of 26 patients participated in this study. Data were collected in 3 stages, including one focus group (stage 1, $n = 6$) and 2 rounds of 10 in-depth, semistructured individual interviews (stage 2, $n = 10$; and stage 3, $n = 10$). We chose a multi-method design in order to gain understanding from multiple perspectives that could inform content and information delivery decisions to the final DIAMANTE intervention. We expected that recruiting approximately 10 patients for each stage of the study would be enough to iterate study materials and provide enough qualitative data and feedback for the final DIAMANTE intervention. The sample included participants with diabetes and depression. Data on diagnosis of depression and diabetes were collected from the electronic medical records before participants were contacted for recruitment. Inclusion criteria for all stages included: ≥18 years old, English or Spanish speaking abilities, mobile phone ownership and having a diagnosis of depression. Exclusion criteria were active suicidal ideation with a plan and active, severe psychosis. Participants were recruited through phone calls, and scheduled for an in-person interview at the study office, if they met inclusion criteria.

Data collection procedure
In all stages, informed consent was obtained from participants prior to the start of each interview. Additionally, sociodemographic information (such as race, age, and gender) and health status were collected using a questionnaire.

Participants in stage 1 and 2 were recruited after they had participated in a clinical trial utilizing text messaging as an adjunct to cognitive behavioral therapy for depression conducted by AA. We recruited participants from the depression texting intervention[16] in order to understand participant's overall experience, as well as barriers to using an mHealth intervention that utilized a text-messaging component.

In stage 1, we conducted a focus group in Spanish. PAG, and a research staff member, both bilingual and bicultural with several years of experience conducting research in safety-net health care settings facilitated the discussion; which focused on participant's overall experience using text messages as part of depression treatment, feedback of text message characteristics, including content, frequency and timing, and acceptability of mobile health technologies. The focus group lasted 2 h and participants were compensated with a $50 gift card.

We used the information gathered in the focus group to refine questions for the interview guide used in stage 2 and focused on barriers and benefits of participating in the texting intervention, physical activity, and mobile phone use. Each interview lasted 1.5 h and participants were compensated with $37.50 gift cards.

Participants in stage 3 had not participated in the previously mentioned mHealth intervention and were also recruited from primary care. Additional inclusion criteria for stage 3 included: not currently pregnant, not currently participating in vigorous physical activity for more than 30 min a day, did not have walking limitations due to disability or medical condition, and ownership of a smartphone; which were set on the basis of matching the health characteristic/abilities of end users for the DIAMANTE intervention. The interviews focused on physical activity barriers and facilitators, mobile phone/text-messaging use, and specific message content. Each of the interviews lasted 1.5 h and participants were compensated with $30 gift cards.

The individual interviews in stage 2 and 3 with Spanish speaking participants were conducted by PAG with the assistance of other bilingual research staff. The interviews with English speaking participants were conducted by research staff fluent in English. The interviewers had training in psychology and qualitative data collection. All individual interviews were audio recorded. Sample interview questions for each stage can be found in Supplementary Appendix A.

Qualitative analysis
Research staff manually transcribed the focus group as it went on. Additionally, PAG and the co-facilitator took field notes while the group was in session. The field notes and real-time transcription were triangulated for consensus. A final transcription was created based on this. The audio-recordings for the semistructured

individual interviews in stage 2 and 3 were sent to a professional transcription service. Individual interviews conducted in Spanish were transcribed in Spanish by the professional transcription service and coded by PAG and SN who are proficient in English and Spanish.

Transcripts were uploaded to Dedoose, a qualitative software program (Dedoose Version 8.1.8, Los Angeles, CA, USA). First, PAG read the interviews in their entirety, using the semistructured format of the interview guides to code for the categories represented in the interview guide: physical activity, current technology use, and depressive symptoms. Within these categories, the transcripts were then open-coded to generate themes related to the format and functionality of digital health interventions, and the impact of digital health platforms on their depression and current barriers to and facilitators of physical activity. PAG created an initial codebook, meeting with SN and CL to discuss emerging themes. Then, SN read a subset of transcripts and coded using the original PAG's codebook, and the all co-authors met to agree on the final set of themes for this analysis.

Ethical considerations

All procedures and materials were approved by the University of California, San Francisco Institutional Review Board Committee.

RESULTS

Participant characteristics

Table 1 summarizes participant characteristics overall and by study stage. Participant mean age was 56.2 years (±9.7), 69% were female, 65% identified as Hispanic/Latino(a), 62% were interviewed in Spanish, 54% were single, and 46% reported having less than a high school education. Half were disabled or receiving disability benefits, all had depression and 62% had diabetes. The majority of participants owned a smartphone (88%).

Qualitative results

Qualitative analysis revealed key themes about barriers to previously engaging in the texting intervention and themes about population specific needs. Tables 2 and 3 summarize key themes and contain illustrative quotes from participants.

Important characteristics for engaging in a texting intervention

Participants frequently described difficulty responding to text messages. When providing feedback for the previous mHealth intervention, a participant suggested: "Shorter [sentences], less complicated" (Spanish PT1, stage 1). Participants also mentioned literacy barriers, as illustrated with this quote: "I like the text messages but my experience is that I'm really bad with the spelling and everything, so I try to avoid writing as much as possible but I just try to write very short..." (English PT9, stage 1).

Participants reported technical barriers and challenges using smartphones or adapting to newer phone models and figuring out how to send and receive text messages (Table 2). Some participants also described low digital literacy. For example, they found newer technology such as smartphone apps and computers as being complicated to use. Finally, we found it was common for participants to report being away from their mobile phone for long periods of time, with many reporting turning the phone off throughout the day or not checking it for notifications consistently.

Participants' relationship with physical activity

We found that knowledge of clinical physical activity guidelines varied among participants. When shown sample messages about physical activity, participants often reacted to messages mentioning 10 000 steps as a daily goal with uncertainty. One participant was unsure of how long, in minutes, it took to walk 10 000 steps: "[The message] says walking for an average of 10 000 steps... but is that many steps the same as walking for 30 minutes?" (Spanish PT13, stage 3).

The types of physical activity that participants currently engage in also varied. More than half described engaging in light, aerobic physical activity such as walking and doing stretches. Several participants engaged in moderate levels of physical activity such as dancing Zumba, bicycling, and swimming. Only 2 participants described engaging in more vigorous levels of physical activity and only a few did physical activity at a gym. As one participant explained, "The gym is not the only place to do exercise...you have the mentality, 'I'm going to get a membership' but it is expensive, there are other options for doing exercise" (Spanish PT16, stage 3).

Chronic pain and physical limitations are barriers to physical activity

The most common health-related barriers reported were experiencing chronic pain and physical limitations. Almost all participants referenced including back, knee, hip, and nerve pain. For many, physical limitations resulting from prior surgical operations, strokes, and injuries were also a barrier: "Yes, I would like to go [walking] often but sometimes because of the diseases that I have... arthritis in one knee, and the other one I have operated on, sometimes I have a lot of pain and I cannot walk" (Spanish PT14, stage 3). Many participants reported only being able to walk a few minutes or short distances at a time before feeling tired or discomfort and having to take a break. Many participants mentioned using a walking device such as a cane or brought a cane with them to the interview.

The role of depressive symptoms

Given that patients in primary care with depression and diabetes compose target population of the intervention, we explored the role that depression played in participants' engagement in physical activity and in their daily lives. Several participants explained how depressive symptoms affected their mood, motivation, and energy not just in relation to physical activity but also in other aspects of their lives. Specifically, descriptions of having low motivation, lack of interest, and loss of pleasure were common among participants. Some described wanting to be in bed or not feeling motivated to interact with others. Insomnia and low energy were also mentioned as reasons for low or no engagement in physical activity. Participants reported wanting messages that motivated them not just to do physical activity but to also provide overall motivation in the context of improving mood and self-efficacy.

Benefits of physical activity as a motivator and facilitator

Both psychological and health benefits of physical activity were noted, such as feeling relaxed, coping with stress, and improved mood: "If you don't [exercise] you gain weight, if you do not go out you get more depressed because of your obesity" (Spanish PT13, stage 3). A few participants also discussed how their sleep improved from having engaged in physical activity. Longevity, improved quality of life, and disease management and prevention were also

Table 1. Patient characteristics

Characteristic	Overall (N = 26)	Stage 1[a] (n = 6)	Stage 2[b] (n = 10)	Stage 3[b] (n = 10)
Age, mean	56.2	47.0	57.8	60.1
Interview language, *n* (%)				
Spanish	16 (62)	6 (100)	5 (50)	5 (50)
English	10 (38)	0 (0)	5 (50)	5 (50)
Gender[c], *n* (%)				
Female	18 (69)	5 (83)	6 (60)	7 (70)
Ethnicity, *n* (%)				
White or Caucasian	2 (8)	0 (0)	2 (20)	0 (0)
Black or African American	4 (15)	0 (0)	2 (20)	2 (20)
Hispanic/Latino(a)	17 (65)	6 (100)	6 (60)	5 (50)
Asian or Pacific Islander/other	3 (12)	0 (0)	0 (0)	3 (30)
Marital status, *n* (%)				
Single	13 (54)	4 (67)	6 (75)	3 (30)
Married or partnered	6 (25)	1 (17)	1 (13)	4 (40)
Divorced	2 (8)	1 (17)	1 (13)	0 (0)
Widowed	3 (13)	0 (0)	0 (0)	3 (30)
Education, *n* (%)				
High school or less	14 (54)	5 (83)	3 (30)	6 (60)
More than high school	12 (46)	1 (17)	7 (70)	4 (40)
Employment status, *n* (%)				
Disabled/on disability	13 (50)	4 (67)	5 (50)	4 (40)
Part-time or more	5 (19)	1 (17)	1 (10)	3 (30)
Unemployed	4 (15)	0 (0)	3 (30)	1 (10)
Retired	4 (15)	1 (17)	1 (10)	2 (20)
Clinical characteristics				
Depression, *n* (%)	26 (100)	6 (100)	10 (100)	10 (100)
Diabetes, *n* (%)	16 (62)	2 (33)	5 (50)	9 (90)
Phone type, *n* (%)				
Smartphone	21 (88)	3 (75)	8 (80)	10 (100)
Basic phone	3 (12)	1 (25)	2 (20)	0 (0)

[a]Stage 1 refers to a focus group of patients previously enrolled in an mHealth intervention.

[b]Stage 2 refers to individual interviews semistructured interviews with patients previously enrolled in an mHealth intervention and stage 3 refers to individual semistructured interviews with patients not previously enrolled in mHealth interventions.

[c]Response options included "female," "male," and "other." Results for this question are reported by number of participants selecting "female." The rest of the respondents selected "male."

Table 2. Themes derived about the mHealth intervention format and functionality

Themes	Illustrative quotes[a]
Literacy level	"I can read the messages and everything. If I do not understand it, I'll read it again. But to reply, I would have a harder time." (Spanish PT14, stage 3)
	"Receiving messages is not difficult. What is sometimes difficult is to send messages… because sometimes I find it hard to write. I only went to second grade. I did not have an education." (Spanish PT13, stage 3)
Difficulty texting	"I did not feel good because I could not answer. I was afraid of pressing the wrong button and erasing the message." (Spanish PT9, stage 2)
	"Now, I just got this phone and before I could use text messages and now I forgot how. I'll have to learn to do it again." (Spanish PT12, stage 3)
	"The truth is that my wife and I, we cannot use [mobile phones]. She uses it a little more than before, but I do not. Before, we had devices with little power, nothing like the phones that exist now." (Spanish PT15, stage 3)
Digital literacy	"I'm not up to date on technology, nor on a computer, or texting." (Spanish PT4, stage 1)
	"Yeah, I know [the step tracker] is there but I'm just somehow not interested… or too complicated. I don't know. I'm just trying to make [it simple] I guess." (English PT5, stage 3)
	"Right now, I'm using the phone to try to find medications and things that might help me." (Spanish PT12, stage 3)
Level of mobile phone use	"I only use it for emergencies. If someone wants to communicate with me, the phone is there." (Spanish PT6, stage 1)
	"If I'm at home, I don't carry it around in my pocket but it's there and I can usually hear it, you know. But I'm not one of those people that is constantly checking." (English PT2, stage 2)
	"There are many times, because I am very disorganized, that I forget the phone when I go take care of my granddaughter. The other day this week I forgot the phone there for like two days." (Spanish PT8, stage 2)

[a]Quotes from Spanish speaking participants have been translated to English.

Table 3. Key themes derived about participants with depression and chronic illness and their engagement in physical activity

Themes	Illustrative Quotes[a]
Engagement in physical activity	
Knowledge of recommendations	"I forget how many thousands [of steps] I need to make, this much or that much. I do not know." (English PT10, stage 3)
	"I didn't like [the message] because I don't believe you can take 10 000 steps. I will have to count them myself when I go walking (laugh). It seems like a lot." (Spanish PT13, stage 3)
Level of engagement	"I go out to walk." (Spanish PT9, stage 2)
	"I don't run because I have like paralysis on my left side but I do a little walking on the treadmill." (English PT8, stage 3)
	"My husband says that we should go to the gym…I stopped going because… I prefer going walking than what you do there." (Spanish PT13, stage 3)
Barriers to physical activity	
Chronic pain and physical limitations	"When I go walk, I walk like a half hour, although my knee hurts…It depends on how my back and knee hurt… when it hurts a lot, I walk about fifteen minutes and slowly, slowly." (Spanish PT9, stage 2)
	"I'll walk but the thing is, you know, when I walk my hip hurts. I got an injection in this one but I don't want to throw my hips off, then I have to have hip replacement." (Spanish PT8, stage 3)
	"…because of the problems I have in my body, I no longer have the same encouragement as before … I have a bad sciatic nerve. I have problems in my spinal column."(Spanish PT15, stage 3)
	"…If I walk too far my limb hurts. And when that happens I have to take my prosthetic off so that the blood circulation can reform." (English PT5, stage 2)
Depression	
Low motivation	"I'm losing my energy, like just not having energy, you know. Just tired and not motivated then for some reason, you know." (English PT9, stage 2)
	"Depression sometimes… it can get someone in a dead end… when I get depression I do not want to see anyone, I want to be alone and sometimes, that's what depression does, pull one back instead of pulling forward. It's what happened to me." (Spanish PT14, stage 3)
Lack of interest and pleasure	"I do not take care of myself at all. My daughter told me to go to the gym, that she will help me pay for it… but since I'm lazy that after going this time I don't want to go again. I just come home and I get into bed…" (Spanish PT7, stage 2)
	"My depression sometimes … It may be very good and I am motivated to leave. But, there are days that I do not even want to leave my house. I dread being out in the street." (Spanish PT16, stage 3)
Benefits	
Experiencing benefits	"For one thing, you will stay in pretty good shape. For another, you'll maintain your weight which is a big deal." (English PT10, stage 3)
	"When I'm exercising, pretty much I can take my mind off of the other [things] and leave it at the door, you know? It helps me sleep better at night. I'm tired. It's a great feeling, having sore muscles and that's apart from an injury as opposed to being injured." (English PT4, stage 2)
	"It makes me feel good, you know, and it make me appreciate life, while I'm feeling good doing exercise, you know. A lot of positive thought comes in, and I sleep better… it's [a] benefit for controlling your diabetes and high blood pressure and heart disease, pretty much to stay healthy." (English PT9, stage 3)
	"Because I want to live a little longer. Have good health because all this bothers me too. Because I get tired of walking now but it's because I'm almost 200 pounds. The doctor told me that everything hurts me, so to take care of myself." (Spanish PT7, stage 2).
Self-efficacy	
Self-motivation and encouragement	"I look in the mirror and I say, 'son, do you want to look like this or you want to get back to where you were?'… and I'm out the door." (English PT10, stage 3)
	"If I do not take care of myself, nobody will take care of me…I feel motivated on my own, it's not necessary to motivate me." (Spanish PT13, stage 2)
Social or peer influence	
Physical activity as a social activity	"[Exercising with other people] helps motivate to be around people…And I met so many people since I've been exercising… you need that encouragement from people…" (English PT1, stage 2)
	"Plus in those [areas] in San Francisco, [exercise] is more of a social thing to do…everyone is always bike riding or jogging or some activity in which they socialize as well as working out." (English PT5, stage 2)
Motivated by others	"I am motivated by my children. When they see me staying in the house, lying down, they call and they come to visit me… they lift me up… because they know that when I'm sleeping, I have depression." (Spanish PT14, stage 3)
	"This older lady…she walks around …like five times, three times a day…and that's my motivation. I'm like, 'I'm gonna just try.'" (English PT8, stage 3)
Lack of social support	"… nobody is going to cheer me up. I have to encourage myself. I do not have anyone in the house who will cheer me up. I'm the one that has to encourage them, that's why." (Spanish PT13, stage 3)
	"I'm very happy about the messages because I say, 'there are people who are remembering me when not even my family has called me." (Spanish PT6, stage 1)

Table 3. continued

Themes	Illustrative Quotes[a]
Opportunity cues for physical activity	
Created cues	"There's a gym just two blocks away from the place [where] I live and I just, train myself just to take a shower and everything in the gym so I don't use the bathroom in my house because I'll go [at the gym]." (English PT9, stage 3)
Environmental	"When I go to the mall, I prefer that walking rather than just around the block ...it's like I don't see anything... but in the mall, I can see a lot of things and I enjoy it so I can make this more a walking exercise." (English PT7, stage 3)

[a]Quotes from Spanish speaking participants have been translated to English.

benefits described by participants: "The best motivation is that I need it. I have heard of people that have had amputations of an arm or leg because of diabetes... that motivates me to go walking" (Spanish PT12, stage 3). These discussions about the benefits of physical activity suggest that participants are motivated by the benefits and changes they have experienced or expect to experience by previously changing or planning to change their behaviors.

Self-efficacy to engage in health behavior change

The role of self-efficacy in health behavior change also emerged as a major theme. Specifically, self-efficacy played a role in facilitating engagement in physical activity. According to participants, self-motivation gets them to initiate in physical activity when they are having a difficult time getting started. For example, one patient describes motivating themselves by thinking about how they felt when they were physically unable to go for a walk: "I talk to myself, 'Come on, just get up'" (English PT8, stage 3). Several participants explained that their source of motivation had to come within to be able to engage in physical activity.

Social or peer influence to engage in physical activity

Social norms about physical activity encouraged some participants to engage in physical activity. Specifically, perceiving physical activity as a social activity, or an activity that would cause enjoyment, influenced several participants to participate in group exercises such as Zumba and stretching or modified exercise classes. Others felt motivated by others and engaged in physical activity with a partner: "I have a friend that will go [walking] with me, I invite or they call me" (English PT7, stage 3). However, several participants also discussed that physical activity was not something they did with others. While some used family as a source of motivation to engage in healthy behaviors, others described lack of support from family or lack of social support in general: "My husband never has time to help, that is the biggest thing. Because there is no company that goes with you...your family sometimes doesn't have time for you" (Spanish PT16, stage 3).

Creating opportunity cues for physical activity

Participants emphasized wanting messages that provide suggestions on how to be more active and wanted to be prompted with reminders of how and when to initiate physical activity throughout the day. For example, one participant said: "That's exactly what would motivate me, to be told 'Get up, go out, walk...look, it's a nice day. Go for a walk...'" (Spanish PT12, stage 3). Another participant creates the opportunity to walk more by choosing to walk the rest of the way home instead of taking the bus from work: "If the

bus passes, I can take it but...I walk one, two, three stops...four blocks. I walk a lot" (Spanish PT13, stage 3).

DISCUSSION

We found that patients with depression and comorbid chronic illnesses (primarily diabetes) in low-income settings experience barriers to engaging with mobile phone technologies and physical activity. By assessing these barriers, this data can be used to make design decisions related to the content and technological delivery of the intervention. Although ownership was high, some patients expressed difficulty reading and understanding text messages and difficulty using mobile phones. We also found that our target population experiences additional barriers to physical activity related to having comorbid health conditions that cause chronic pain and having depression. These findings correlate with previous studies in which common barriers among low-income adults included low social support, medical, and physical barriers to activity (eg joint or leg pain) and chronic pain.[12,25,26] Regarding text message content, and consistent with previous research, we found that participants want to receive motivational and positive messages that encourage and remind them to engage physical activity.[27,28]

Based on the findings of our study, we identified key design decisions about message content and information delivery for the DIAMANTE trial (Table 4).

Design decisions made regarding text message content and characteristics

The main content categories for the text messages delivered in the DIAMANTE trial will be: opportunity cues, benefits, and self-efficacy, with individual, social orientations. Given that participants used and created opportunities to engage in physical activity, we draw from the opportunity cues construct (concrete strategies to engage in physical activity) in the capability, opportunity, and motivation behavior system (COM-B model[29]) and include opportunity cues as a content category for the text messages. In addition, focusing on the benefits of physical activity, the benefits category will deliver content that uses physical and social outcome expectation as a motivator to do physical activity. Finally, text messages in the self-efficacy category will focus on increasing self-efficacy both directly, by providing motivation and increasing participant's confidence and indirectly, by proving tips to build skills that increase self-efficacy as guided by social cognitive theory.[30] We also identified that pain was the most common barrier to physical activity experienced in our target population. As a result, we are integrating other types of disease management and pain management messages and messages that

Table 4. Intervention needs identified and resulting design decisions and considerations

Intervention needs identified	Design decisions made to the DIAMANTE intervention
Text messages	Three motivation categories:
Content of text messages	1. Messages to increase self-efficacy
	2. Messages emphasizing benefits
	3. Messages that elicit opportunity cues
Messaging characteristics	Include range of suggestions of types of physical activity
	Messages that remind participants to do physical activities
	One-way messaging
	Lower literacy level
Physical activity education	
Goal setting	All participants will receive baseline physical activity education
	Baseline daily step goal relative to average steps in the past week or minimum of 4000, whichever is higher
Assessment of social isolation	Feedback messages will include relative to goal terms instead of numerical values
	Level of social isolation at baseline will determine whether participants receive family-related messages.
Assessment of physical mobility	Level of ambulation will be assessed to determine eligibility to participate in the study

motivate participants to manage their pain and prevent it from limiting their physical activity. We will also include messages that target improvement of specific depressive symptoms with the purpose of increasing behavioral activation.

Information delivery decisions

Findings related to engagement highlight the need for content that is written at a lower reading level. Given almost half of the participants reported less than a high school education, we decided to make the messages more inclusive by writing them at a fifth grade reading level. In addition, given participants' concerns with limited ability to reply to messages, we do not expect participants to provide a response and will make the messages one-way. We will also deliver text messages to remind participants to carry their phones with them and provide information on how step tracking using mobile phones works and emphasize that participants need to carry keep their phone turned on as much as possible.

The range of current physical activity, knowledge of recommended duration and intensity, engagement in various different activities suggests that baseline health education is a crucial component that should be considered in the intervention. As such, 2 key decisions were made regarding study procedures: (1) all participants will receive health education regarding the recommended daily number of steps and (2) research staff will employ health coaching to set the daily step goal at baseline with the participant. To address the different levels of activity and types of physical activity the target populations engages in, we will deliver messages that encourage and suggest different forms of increasing daily activity. Furthermore, to address the varied understanding of step count, for the DIAMANTE trial, we will mostly deliver feedback on meeting the daily step goal in relative terms (eg "You walked less/more than your goal," "You did/did not meet your goal") instead of in absolute terms (eg "You walked 5000 steps less than your goal.").

The prevalence of physical limitations, and limited ambulation among participants also has implications for intervention uptake such that we are now re-visiting eligibility criteria and how daily step goals are determined at baseline. The decisions made include screening for level of ambulation and realistic goal setting of daily steps (4000 steps or average daily steps from the last week) for people living with disability and/or chronic illness limiting mobility as determined appropriate by other studies.[31]

While we found that participants may be motivated by others around them engaging in physical activity, social support may not act as a motivator for participants experiencing social isolation or lack of support. Because many participants described experiencing social isolation or not having support from family, we plan to assess family support at baseline. Participants with low or no family support will not receive messages that mention using family as a motivation for doing physical activity.

While studies have assessed the acceptability of text messages and have used participatory design to develop message content,[17,18,32,33] most have used developed expert content[8,34] or been guided by theories about behavior change.[35–37] Despite the advantages of the approach, few studies have engaged vulnerable populations to investigate intervention features and components that are important to end users. For example, Ramirez et al used a survey method to determine intervention features that were important to urban, low income Latino patients with diabetes (ie frequency of text messages and physical activity behavior change education) that could support improvement in their physical activity.[17] King et al conducted 12 months of formative participatory research among older adults with low-income and low-literacy levels to enhance cultural and linguistic congruity that led to an intervention that significantly increased walking time.[19]

In order to fully assess adoption and uptake of the decisions made, the next step in the development of the DIAMANTE intervention will be to pretest the intervention with end users. This will be done using an "in the wild" approach in which technological interventions are evaluated in a real-world context to assess how users interact with the intervention outside the lab, or research setting.[38] This method will allow for further refinement based on user feedback and will increase the appropriateness of the content and usability of the technology.

Limitations

There are several limitations to this study. While we looked at the themes across the whole sample, it is possible that there are differences between subgroups that we did not capture based on language, cultural, or socioeconomic factors. In addition, 16 of the participants in this sample had already participated in a text-message based, mHealth study, and could have decided to participate in interviews if they had a strong opinion about the intervention. Lastly, the inclusion and exclusion criteria for participation in the

study could have implications on the experiences captured in the interviews. For example, excluding individuals who do not own a mobile phone may have implications for understanding barriers to engaging in physical activity specific to this population or to other interventions that are not smartphone based.

CONCLUSIONS

mHealth interventions can reduce health disparities, but only when they meet the needs of the users and when those who would benefit the most adopt and engage in them. Our team made key decisions to simplify content, set reasonable goals, and target relevant motivators based on user feedback. Conducting qualitative research with end users of an mHealth intervention to increase physical activity allows intervention developers to tailor and modify components of the final intervention to be most relevant and engaging to participants. The UCD design strategies, such as those provided in this article can help inform the broader field and lead to a more equitable adoption and use of mHealth interventions by traditionally underserved populations.

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AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception and drafting of the manuscript. PAG, SN, AC, CL, and US designed the study, implemented the methods, and carried out the qualitative analysis. PAG, RH, and AA led the majority of the writing. All authors reviewing and revising critically for final approval of the version to be published.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

CONFLICT OF INTEREST STATEMENT

None declared.

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