Development and evaluation of the See Me Smoke-Free multi-behavioral mHealth app for women smokers

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Abstract

Women face particular challenges when quitting smoking, especially those with weight concerns. A multi-behavioral smoking cessation intervention addressing these concerns and incorporating guided imagery may assist women to engage in healthy lifestyle behaviors. An mHealth app can easily disseminate such an intervention. The goals of this pilot study were to develop and test the feasibility and potential of the See Me Smoke-Free™ mHealth app to address smoking, diet, and physical activity among women smokers. We used pragmatic, direct-to-consumer methods to develop and test program content, functionality, and the user interface and conduct a pre-/post-test, 90-day pilot study. We enrolled 151 participants. Attrition was 52%, leaving 73 participants. At 90 days, 47% of participants reported 7-day abstinence and significant increases in physical activity and fruit consumption. Recruitment methods worked well, but similar to other mHealth studies, we experienced high attrition. This study suggests that a guided imagery mHealth app has the potential to address multiple behaviors. Future research should consider different methods to improve retention and assess efficacy.

Keywords

mHealth, Tobacco cessation, Diet, Physical activity, Multi-behavioral, Guided imagery

BACKGROUND

Lung cancer remains the leading cause of cancer death among US women [1]. Over 201,000 women in the USA die annually from smoking-related illnesses [2]. Smoking causes about 80% of chronic obstructive pulmonary disease (COPD) deaths among women [3] and doubles the likelihood that a woman will develop coronary heart disease compared to their non-smoking counterparts [2]. In spite of this, it is encouraging that almost half of women smokers try to quit annually [4], and those who do may experience significant health benefits [5, 6].

Although men and women are equally likely to quit [7], women face particular challenges when quitting smoking [8]. The majority of women who quit smoking gain 8 to 10 lb on average [9–13]. Many women

Implications

Practice: Results suggest that it may be feasible to deliver a multi-behavioral intervention via a mobile health app.

Policy: If found to be effective, tobacco cessation strategies delivered via a mobile health app may be incorporated into medical treatment and covered by health plans.

Research: Further research is needed to test the efficacy of the See Me Smoke-Free app, using improved design considerations, retention strategies, and statistical analyses.

smokers report concerns about weight gain as a barrier to quitting [14–25], and women quitters who return to smoking identify weight gain as a reason for their relapse [26–29]. Women who are highly concerned about their weight are more likely to smoke as a means to control their weight [15, 30, 31]. Many studies have shown that men are significantly less likely than women to report weight concern as a reason for smoking relapse [32–36]. Some studies suggest that women smokers endorse a thinner body image and are less satisfied with their bodies than never smokers [27, 37]. Smoking cessation interventions aimed at women need to consider these weight-related issues.

A small but growing body of literature suggests that a multi-behavioral approach may be particularly helpful for decreasing weight and sedentary activity and may contribute to successful smoking cessation among women [5, 38–42]. Women smokers who already reported an active lifestyle have been shown to have more success quitting and more gradual rates of returning to smoking [43]. According to a meta-analysis by Spring and colleagues [39], combined smoking cessation plus weight treatment resulted in significantly higher short-term abstinence and significantly lower weight gain than did smoking treatment

alone. Other smoking cessation interventions suggest that participation in structured exercise can be an effective smoking cessation strategy compared to general wellness (control) groups [41, 44, 45]. Results from meta-analyses have also shown that physical activity improves body image irrespective of changes in fitness or body weight [46].

Separate lines of inquiry support the use of guided imagery to enhance physical activity, improve diet, and quit smoking [47–51]. Guided imagery is an easily learned cognitive technique in which the user imagines detailed engagement in an activity and involves their emotions and all the senses [52]. Several studies suggest that guided imagery can be effective in assisting smokers to quit [50, 53]. Cross-sectional and intervention studies have documented that adherence to a guided imagery program is correlated with greater motivation to be physically active [47, 54, 55]. Similarly, a growing body of literature suggests that guided imagery can be effective at improving dietary behaviors [48, 56, 57]. These studies suggest that guided imagery may be an effective way to simultaneously increase smoking cessation and engagement with physical activity and dietary behaviors.

Until recently, guided imagery intervention studies have been conducted face to face, which inherently limits access and dissemination. Mobile technology provides the potential for far greater reach of many lifestyle interventions. In 2015, 64% of US adults used a smart phone with enabled Internet capacity, and 62% used their devices to search for health information [58]. According to a recent study, 58% of smart phone users have downloaded a health app [59]. The use of mobile technology allows users easy access to information, resources, and tools for self-management; allows interventions to be tailored; and enables researchers to capture individual patterns of behavior in real time.

Importantly, there is evidence to support the use of mobile technology to successfully address tobacco cessation. A recent Cochrane review of mobile phone-based smoking cessation interventions found 12 studies with 6-month smoking cessation outcomes [60]. Most of these interventions were text based, rather than mobile applications, but the authors concluded that the “current evidence supports a beneficial impact of mobile phone-based smoking cessation interventions on 6-month cessation outcomes” [60]. In addition, there is evidence that mobile technology can be effective for multiple behavior changes in diet and physical activity [40].

The purpose of this study was to develop and evaluate a mobile health application (mHealth app) called See Me Smoke-Free™. The app was designed to help women quit smoking while increasing physical activity and healthy eating through the use of guided imagery and behavioral strategies. The imagery components of See Me Smoke-Free aimed to improve body image, self-efficacy to quit smoking, and manage cravings to

smoke. Behavioral strategies included self-monitoring, rewards for engaging in evidence-based practices, and provision of evidence-based resources.

The aims of the study were to create program content and design the functionality of See Me Smoke-Free for use on one smart phone operating system (i.e., the Android platform) (phase 1); program and test the app’s usability (phase 1); and pilot test the app, including methods for recruitment and retention of participants, and evaluate use of the app (phase 2). Using a single-group pre-/post-test design, we evaluated whether use of the app was associated with tobacco use, dietary behaviors, and physical activity and assessed consumer satisfaction (phase 2). Herein, we report results of phase 2.

METHODS

Overview

This study was conducted from January 2014 to December 2015. This project occurred in two phases. During phase 1, the multi-disciplinary team developed the content and programmed the user interface. In phase 2, we conducted a pilot study of app use. The investigators chose to use a pragmatic, direct-to-consumer approach during phase 2 in order to assess the feasibility of app use in a real-world setting. The strengths of this approach include the ability to implement and test the deployment and technical issues associated with an mHealth app and the potential to assess the reach, adoption, maintenance, and perceived usefulness of the mHealth intervention with its intended audience. The project was reviewed and approved by the University of Arizona Institutional Review Board. Informed consent was obtained from all individual participants included in the study.

Program development

The intervention content and app user interface were refined through focus group discussions and with member checks [61], in which revisions to the app were reviewed by previous focus group participants. Focus groups identified several themes for incorporation into app content (e.g., using positive language, the rewards of smoking cessation, and the integrated benefits of maintaining a healthy lifestyle). User-testing sessions and internal quality control testing identified and addressed functionality issues, content problems, and bugs. Changes to the app content and function were made iteratively by the development team as a result of focus group and user testing until we reached theoretical saturation, and no new insights were developed from data collection [62]. A complete description of the phase 1 development process is contained in a separate publication [63].

Program description

The home screen of the See Me Smoke-Free app displays the amount of time since the user last smoked, average number of daily cravings by week, money

Fig. 1 | See Me Smoke-Free home screen and imagery menu

saved through not purchasing tobacco products, daily messages delivered via the app related to the intervention and/or study, and the icons through which the five additional components of the app are accessed. The See Me Smoke-Free home screen is in Fig. 1. Through the home screen icons, users were able to access five pre-recorded guided imagery audio files and a record-

your-own audio function (see Fig. 1), a tracking calendar, smoking cessation and healthy living resources, awards, and their profile (Table 1).

The team developed five imagery audio files, one of which was a general introduction to guided imagery. Three files were designed to target specific behaviors—smoking cessation, physical activity, and fruit

Table 1 | See Me Smoke-Free components

Guided imagery audio files

- Introduction to guided imagery
- Be smoke-free
- Eat well
- Get moving
- Feel fantastic
- My file (personalized)

Self-monitoring

- Smoking
- Cravings
- Money saved
- Eating five fruits and vegetables
- Getting 30 min of exercise

Push notifications

- Motivational messages
- Tips for quitting, healthy eating, etc.
- Tailored feedback based on user input

Resources for tobacco cessation, diet, and physical activity

- Direct connect to tobacco quitlines
- Links to evidence-based programs, resources, and information
- Contact information for local programs (e.g., cessation programs, farmer's markets, and YMCA)

Awards for meeting goals

- Smoking, diet, and physical activity
- Listening to imagery files

and vegetable consumption—and another addressed general wellness, positive body image, and self-efficacy. The smoking cessation audio file (Be Smoke-Free) focused on visualizing oneself as a non-smoker, feeling the physical benefits of not smoking, being strong, and healthy. The physical activity file (Get Moving) guided the user to visualize engaging in a pleasant physical activity, feeling the effects of that activity on their body, and immersing themselves in the experience. The fruit and vegetable consumption file (Eat Well) encouraged the user to imagine herself in a farmers' market, choosing and eating fresh produce. Users were asked to set a time during the day when they would like to listen to the guided imagery file. The app sent reminders to participants prompting them to listen at the designated time. Participants listened to the Be Smoke-Free file for 1 week, followed by 1 week each of Eat Well, Get Moving, and Feel Fantastic. After 4 weeks, the user could record her own audio file, with sample scripts available on the See Me Smoke-Free website.

In addition to the audio files, users received periodic motivational messages, and optional messages designed to provide tips and techniques for successful behavior change based on their stage in the quitting process. The majority of the tips were aimed at quitting smoking, body image, and self-efficacy but shifted to healthy eating and physical activity to correspond to the audio file schedule. Daily questions prompted users to enter data about their smoking status, fruit and vegetable intake, and level of physical activity, which populated the tracking calendar. Based on this input, the app generated awards for goal-setting and achievement, which could be shared on social media (e.g., Facebook and Twitter). There were links to additional resources for smoking cessation, healthy eating, and increasing physical activity. A complete description of program content, including each of the guided imagery audio files, is described in a separate paper [63].

Study procedures

A complete description of the study protocol is contained in a previous paper [64]. Briefly, the See Me Smoke-Free app was available for free download from the Google Play Store. After users downloaded the See Me Smoke-Free app from the Google Play Store and completed the user profile, they received a pop-up notification inviting them to participate in the research study. Users who answered either “yes” or “tell me more” to the prompt “Your experience using this app can help others. Participate in a University of Arizona research study and earn \$50” were provided information about the research study. Interested respondents were screened for eligibility (i.e., women, smoked in the last 30 days, ≥ 18 years old, US resident, English speaker), and eligible respondents were invited to enroll and complete the baseline survey and were then returned to the new user screen. All of these activities were conducted entirely within the app, with instructions to contact project staff via e-mail or phone with questions or problems. Ineligible users and those

not interested in participating were taken to the new user screen.

The new user screen displayed the purpose of the See Me Smoke-Free app, instructions to use the app “most days for 30 days,” and a brief tutorial whereby users could familiarize themselves with the app's functions. See Me Smoke-Free guided imagery program content was presented in succession, requiring users to listen to each file for 1 week before moving on to the next file. All other functions were available on demand. Once all files were listened to, the user was given the option to record her own file. Sample-guided imagery scripts are available on the See Me Smoke-Free website (www.seemesmokefree.org).

At the end of each day, participants were prompted to answer four questions: (1) “Overall, please rate your cravings today?”; (2) “Did you smoke today, even a puff?”; (3) “Did you eat four servings of fruits and vegetables today?”; and (4) “Did you get at least 30 min of moderate physical activity today?”

Use of the guided imagery files and other See Me Smoke-Free usage data was automatically collected by the app and stored in the study database, allowing staff to generate user reports through a pre-programmed administrative dashboard. Usage data included the number of times the app was opened, daily questions were answered, audio files were started, and audio files were completely played. Since the purpose of the study was to determine feasibility and potential impact of app use, the research team determined that participants had to use the app for “most days” in the first 30 days of the trial in order to remain active participants in the study. Therefore, participants who had no recorded app use for 14 consecutive days were contacted by phone by project staff to determine the reason for non-use (e.g., technical problems, lack of interest in quitting). When participants were reached, their reason(s) was/were recorded. Participants received up to three calls and were reminded to use the app or face administrative withdrawal from the study. Participants who did not use the app after the third phone call reminder were dropped from the study.

Prompts for the follow-up assessments at 1 and 3 months post-enrollment were delivered via the app. Participants completed the follow-up surveys either directly within the app or through a web link to a survey programmed and delivered via Qualtrics research software (www.qualtrics.com). Project staff contacted participants who did not respond to a survey within 1 week. All participant management was conducted using Research Electronic Data Capture (REDCap), which is a secure, web-based application hosted by the University of Arizona designed to support data collection for research studies [65]. Participants received \$25 for completing each follow-up survey, for a total of \$50.

Participant eligibility and recruitment

Recruitment occurred from March 30, 2015 to July 31, 2015. Eligible participants lived in the USA, identified

as female, smoked in the last 30 days, used an Android phone, agreed to use the app “most days for 30 days,” were at least 18 years old, spoke English, and had a valid e-mail address. The recruitment approach consisted entirely of low- and no-cost strategies which focused on “earned” (free) local and national media coverage about the study, as well as Facebook and Twitter postings. These outreach efforts brought potential participants to the study web page where they were provided instructions to download the See Me Smoke-Free app from the Google Play Store. Respondents who downloaded the app were prompted to complete their in-app profile and were subsequently invited to participate in the research study. Respondents who opted into the study provided informed consent, completed the baseline assessment, and were asked to visit the See Me Smoke-Free homepage and begin using the app. Respondents who opted out began to use the app without delay.

Measures

This study collected three types of data: (1) demographic characteristics obtained at baseline to describe the participants, (2) quantitative variables hypothesized to be influenced by the intervention at follow-up, (3) and data collected “in-app” to quantify imagery and other app usage and investigate app use relative to behavioral outcomes.

Baseline demographics—Gender (gathered from the eligibility screening process), age (equal to or greater than 18), race (e.g., African American, American Indian/Native American, Asian, and Caucasian), ethnicity (i.e., Hispanic/Latino, non-Hispanic/Latino), education (highest educational level attained), and marital status (single or married/living with a partner) were collected.

Tobacco related—The following variables were collected: current tobacco use (“During the past 7 days have you smoked, even a puff?” Yes/no) and tobacco use history (“How many years have you smoked?”). Nicotine dependence was assessed using the Fagerström item “How soon after you wake up do you usually smoke your first cigarette?” based on previous research showing this one item to be most predictive of abstinence [66–70]. Readiness to quit (using the Biener and Abrams Contemplation Ladder; 0 = not ready to quit to 10 = ready to quit now) [71] and self-efficacy to quit smoking (using five items from the Condiotte and Lichtenstein Confidence Questionnaire) [72] were administered at baseline and re-assessed during follow-up measurement points based on the answer to current tobacco use. At follow-up, point prevalence of smoking (i.e., last 7 days) and prolonged abstinence (e.g., last 30 days) were also evaluated.

Weight related—Self-reported weight was assessed by the question “How much do you weigh without clothes or shoes?” (in pounds). Self-reported height was assessed by the question “How tall are you without shoes?” (with separate dropdown boxes for feet and inches). Smoking as a strategy for weight control and weight concern were assessed by three items

adapted from Pomerleau and colleagues [73] and Borrelli and Mermelstein [74]: “Smoking helps me control my appetite,” “I do not get so hungry when I smoke,” and “Please rate how willing you would be to gain 1–5 lb when you quit smoking.” Body image was assessed using the seven-item Appearance Evaluation Subscale of the Multidimensional Body-Self Relation Questionnaire [75] (e.g., “I like my looks just the way they are,” “Most people would consider me good-looking,” “I like the way my clothes fit me”).

Diet—Ten items to assess typical dietary intake of fruits and vegetables were obtained from the interactive version of the National Cancer Institute Fruit and Vegetable Scan [76].

Exercise behavior—Exercise (within the past week) was measured using the Godin Leisure-Time Exercise Questionnaire (LTEQ) [77, 78], which is sensitive enough to differentiate mild, moderate, and strenuous exercise and can be scored in total number of minutes of activity or as a metabolic equivalent (METs) expenditure estimate.

Withdrawal and craving symptoms—Within the app, participants rated their average withdrawal symptoms and cravings at the end of each day using a five-point rating scale of severity [79, 80].

Guided imagery—The app automatically collected the number of times each participant started and completed listening to the imagery audio files. Behaviors and attitudes regarding guided imagery and relaxation were assessed using four items adapted from Borkovec and Nau [81]: (1) “How many minutes per day during the past week did you practice visualization or guided imagery?”; (2) “How many minutes per day during the past week did you practice breathing, meditation, or progressive relaxation?”; (3) “How confident do you feel that guided imagery can help you to quit smoking?”; and (4) “How logical does the use of guided imagery to quit smoking seem to you?”

App satisfaction and acceptability—At the 30-day follow-up, See Me Smoke-Free app usability was determined using Tullis and Stetson’s eight-item adaptation [82] of Brooke’s System Usability Scale [83]. Participants were also asked to rate their overall satisfaction with the program, perceived usefulness of information, and whether they would recommend the program to others.

Statistical analyses

Feasibility was assessed post hoc by the number of women recruited and retained. To assess potential impact of app use on behavioral outcomes, we chose to drop all participants who did not use the app and did not impute missing outcome data. Statistical analyses were conducted using IBM SPSS Statistics version 23. McNemar and Wilcoxon signed-ranked tests were used to assess change in measures across time. For the purposes of this pilot study, statistical significance was set at $p < 0.01$ to control for multiple comparisons.

Table 2 | Baseline participant characteristics

	Mean (SD)
Age	39.1 (13.1)
	<i>N</i> (%)
Race	
African American	12 (16.4%)
Asian	1 (1.4%)
Caucasian	53 (72.6%)
Multi-race/other	3 (9.6%)
Other	4 (5.5%)
Ethnicity	
Hispanic/Latino (any race)	6 (8.2%)
Education	
<High school	3 (4.1%)
High school graduate or equivalent	22 (30.1%)
Some college	25 (37.0%)
College graduate	16 (21.9%)
Post-college	5 (6.8%)
Marital status	
Single	42 (57.5%)
Tobacco use	
Smoked last 30 days	73 (100%)
Smoked last 7 days	70 (95.9%)
Time to smoke after waking	23 (31.5%)
<5 min	29 (39.7%)
5–30 min	17 (20.5%)
31–60 min	6 (8.2%)
>60 min	
Used e-cigarettes in past 30 days	25 (34.2%)
	Mean (SD)
Years smoked	19.2 (12.9)
Cigarettes per day	16.0 (13.2)
Contemplation ladder	7.9 (1.91)
Confidence in quitting ^a	3.62 (0.67)
Weight	
Weight	169.8 (43.0)
Concern about weight gain ^a	3.15 (0.68)
Body image ^a	3.08 (0.76)
Diet	
Frequency of fruit intake ^b	3.70 (1.91)
Frequency of vegetable intake ^b	4.47 (1.72)
Frequency of water intake ^b	6.74 (2.68)
Frequency of juice intake ^b	3.10 (2.02)
Exercise	
Mild, moderate, and strenuous minutes	171.5 (154.8)
Physical activity METs	25.48 (23.75)
Work up a sweat ^c	2.53 (0.90)
Guided imagery	
Daily minutes of guided imagery ^d	1.77 (1.19)
Daily minutes of relaxation/meditation ^d	1.89 (1.17)
Confidence in guided imagery to quit smoking ^e	3.16 (0.88)
How logical is using guided imagery to quit smoking ^f	3.33 (1.01)

^a 1 = low to 5 = high^b 1 = never, 2 = 1–3 times/month, 3 = 1–2 times/week, 4 = 3–4 times/week, 5 = 5–6 times/week, 6 = 1 times/day, 7 = 2 times/day, 8 = 3 times/day, 9 = 4 times/day, 10 = 5 times/day^c 1 = never to 5 = always^d 1 = never to 5 = more than 30 min^e 1 = very unconfident to 5 = very confident^f 1 = very illogical to 5 = very logical

RESULTS

Participant characteristics

Participant characteristics are described in Table 2.

Study recruitment, engagement, and retention

Recruitment and enrollment

Our initial aim was to recruit 50 participants for this study. However, during the recruitment period, the See Me Smoke-Free app was downloaded and installed by 289 potential participants. Of those, 151 (52%) enrolled in the study. All enrollees were women.

Engagement

Of the 151 enrolled participants, 78 (52%) were either dropped from the study due to inactivity or withdrew from the study, leaving a final sample of

73 (48%). All dropped or withdrawn participants were asked to complete a brief exit survey. Study staff attempted to contact those who did not complete the exit survey, but only 20 (26%) of the dropped/withdrawn participants spoke with study staff or completed the survey. They reported the following reasons for stopping participation (some reported more than one): 30% (6) of participants reported technical issues with the app or the phone, 20% (4) reported difficulty quitting, 15% (3) responded that it was not a good time to quit, 10% (2) felt the app was not helping them quit, 5% (1) misunderstood the app's purpose or never used the app, and 15% (3) did not identify a reason for withdrawing from the study (see Fig. 2.) No significant differences were found in baseline variables between participants in the final sample and those who were dropped/withdrawn.

Fig. 2 | Participant flow

Table 3 | See Me Smoke-Free feasibility study changes in outcomes

	Baseline (%)	30-day (%)	90-day (%)
Smoking abstinence			
Abstinence last 7 days ^a (<i>n</i> = 63) ⁱ	1.6	36.5**	47.6**
Abstinence last 30 days ^b (<i>n</i> = 63) ⁱ	0.0	19.0	33.3*
	Mean (SD)	Mean (SD)	Mean (SD)
Number of cigarettes smoked per day and confidence in quitting among smokers			
Number of cigarettes smoked per day ^a (<i>n</i> = 32) ⁱ	16.7 (7.5)	12.2** (6.7)	11.1** (7.1)
Confidence in quitting ^c (<i>n</i> = 32) ⁱ	2.9 (0.9)	2.5 (0.9)	2.3 (0.9)
Diet			
In last month, frequency of fruit intake ^{a,d} (<i>n</i> = 62) ⁱ	3.8 (1.9)	4.5* (2.0)	5.0** (2.2)
In last month, frequency of vegetable intake ^{a,d} (<i>n</i> = 62) ⁱ	4.5 (1.8)	4.8 (1.6)	4.9 (2.0)
In last month, frequency of water intake ^{a,d} (<i>n</i> = 62) ⁱ	6.5 (2.8)	7.2* (2.4)	7.4** (2.5)
In last month, frequency of juice intake ^{a,d} (<i>n</i> = 62) ⁱ	3.2 (2.1)	3.7 (2.2)	3.9 (2.2)
Exercise			
Minutes of exercise during typical week (<i>n</i> = 60) ^{i,a}	172 (157)	273** (196)	269** (161)
How often sweat is worked up during typical week (<i>n</i> = 62) ^{i,a,e}	2.5 (0.9)	3.1** (0.9)	3.2** (0.9)
Weight and body image			
Weight (<i>n</i> = 60) ⁱ	170.3 (45.0)	170.6 (43.3)	169.1 (44.5)
Body image ^c (<i>n</i> = 62) ⁱ	3.1 (0.8)	3.2 (0.9)	3.1 (0.8)
Concern about weight gain ^c (<i>n</i> = 21) ⁱ	3.0 (0.7)	2.8 (0.8)	2.6 (0.9)
Guided imagery behaviors and attitudes			
In past week, minutes per day of visualization ^{a,f} (<i>n</i> = 62) ⁱ	1.8 (1.2)	2.8** (1.1)	2.7** (1.2)
In past week, minutes per day of relaxation ^{a,f} (<i>n</i> = 62) ⁱ	1.8 (1.2)	2.9** (1.1)	2.9** (1.3)
Confidence in guided imagery to quit smoking ^{a,g} (<i>n</i> = 62) ⁱ	3.2 (0.9)	3.2 (1.0)	3.2 (1.2)
Logical to use guided imagery ^{a,h} (<i>n</i> = 62) ⁱ	3.5 (0.8)	3.4 (1.1)	3.7 (1.0)

p* < 0.01*p* < 0.001^a Compared to baseline^b Comparison of 30 to 90 days^c 1 = low to 5 = high^d 1 = never, 2 = 1–3 times/month, 3 = 1–2 times/week, 4 = 3–4 times/week, 5 = 5–6 times/week, 6 = 1 times/day, 7 = 2 times/day, 8 = 3 times/day, 9 = 4 times/day, 10 = 5 times/day^e 1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always^f 1 = never, 2 = <10 min, 3 = 10–20 min, 4 = 20–30 min, 5 = 30+ min^g 1 = very unconfident, 2 = unconfident, 3 = somewhat confident, 4 = confident, 5 = very confident^h 1 = very illogical, 2 = illogical, 3 = somewhat logical, 4 = logical, 5 = very logicalⁱ Number of participants with data at all three assessments

Retention

Sixty eight (93%) of the final 73 participants completed 30-day assessments, and 66 (90%) completed 90-day assessments.

Consumer satisfaction and acceptability

At the 30-day assessment, participants reported moderate levels of satisfaction with the See Me Smoke-Free app. Overall, on a scale of 1–5, where 1 is low and 5 is high, participants liked See Me Smoke-Free (mean = 3.72; SD = 0.85), would recommend it to others (mean = 3.91; SD = 0.92), and planned to continue using the app (mean = 3.91; SD = 1.01). In addition, participants would recommend the use of guided imagery to others for quitting smoking (mean = 3.25; SD = 0.80) and planned to continue using guided imagery themselves (mean = 3.57; SD = 1.05).

Evaluation of app use on health outcomes

Changes in tobacco use outcomes

Table 3 shows the changes in reported tobacco use from baseline to both follow-ups and between the 30- and 90-day assessments. Significant differences were found in 7-day abstinence between baseline and both follow-up assessments, as well as in 30-day abstinence between the 30- and 90-day follow-ups. Specifically, self-reported 7-day abstinence was 37% at 30 days ($p < 0.001$) and 47% at 90 days ($p < 0.001$) compared to 4% at baseline. Participants reported 30-day abstinence rates of 21% at the 30-day assessment and 32% at the 90-day assessment ($p > 0.05$, comparing 30- to 90-day follow-ups), although this increase was not statistically significant. Of those participants who continued to smoke ($n = 32$), the number of cigarettes smoked per day changed from 17 at baseline to 12 at 30 days and 11 at 90 days ($p < 0.001$). Confidence in quitting decreased from 3.62 (on a scale of 1–5, where 1 = no confidence to 5 = high confidence) at baseline to 3.35 at the 30-day assessment and 3.13 at 90 days ($p < 0.01$).

Relation of imagery file use to smoking status—We analyzed the relationship between the median number of audio files completed and self-reported cessation at both the 30- and 90-day follow-ups. At 30 days, there were no significant differences between number of audio files completed and 7- or 30-day abstinence. At 90 days, median number of audio files completed was positively associated with both 7-day abstinence ($p < 0.001$) and 30-day abstinence ($p < 0.01$). The median number of audio files completed was 10 for women who smoked within the past 7 days ($n = 33$) and 43.5 for women who did not smoke ($n = 30$; $p < 0.001$). The median number of audio files completed was 13.5 for women who smoked within the past 30 days ($n = 42$) and 47 for women who did not smoke ($n = 21$; $p < 0.01$).

Changes in diet outcomes

Changes in dietary intake included significant increases in the frequency of fruit and water intake and positive trends in vegetable intake (Table 3). Participants reported an increase in the number of times they consumed fruit from baseline (3.70 = 2–3 times per week) at both 30-day (4.5 = 4–5 times per week; $p < 0.001$) and 90-day (4.92 = 5 times per week; $p < 0.001$) follow-ups. There was also a significant increase in frequency of water intake from baseline (6.50 = 1–2 times per day) to both 30 days (7.24 = 2–3 times per day; $p < 0.01$) and 90 days (7.40 = 2–3 times per day; $p < 0.01$). No significant differences were found in consumption of vegetable portions from baseline to follow-up at either 30 or 90 days.

Changes in exercise outcomes

As displayed in Table 3, there were significant increases in frequency of leisure-time exercise from baseline to follow-up. In comparison to 171.5 min of exercise per week at baseline, at 30 days, participants reported that they averaged 272.5 min of moderate to vigorous exercise during a typical week ($p < 0.001$). At the 90-day assessment, participants reported an average of 269.0 min of weekly moderate to vigorous exercise ($p < 0.001$). In addition, the participants significantly increased the weekly frequency of engaging in a physical activity long enough to work up a sweat, from 2.53 (on a scale from 1 to 5) at baseline to 3.11 at 30 days ($p < 0.001$) and 3.15 at 90 days ($p < 0.001$).

Changes in weight, concern about weight gain, and body image

Among those reporting smoking in the past 30 days ($n = 43$) and at the 90-day follow-up, no significant differences were found in weight from baseline (165.6 lb) to follow-up (161.9 lb). Similarly, those who reported quitting at 90 days ($n = 21$) also indicated that they did not gain weight from baseline (181.33) to follow-up (184.9) (not significantly different), and they were heavier at all time points than those participants who did not quit. Concern about weight gain if they were to quit smoking was measured for all participants at baseline and for only continuing smokers at each of the follow-up assessments. Levels of weight concern were moderate at baseline and decreased over time for these participants. However, the differences were not significant. For smokers ($n = 32$), only one item (“Please rate how willing you would be to gain 1–5 lb when you quit smoking”; 1 = low willingness to 5 = high willingness) showed a significant improvement over time, from a mean of 3.13 at baseline to 3.56 ($p < 0.01$) at the 90-day assessment. No significant differences were found in participants’ self-reported body image from baseline to follow-up.

Changes in guided imagery behaviors and attitudes

As shown in Table 3, there were significant increases in the amount of guided imagery in which participants reported engaging during the past week from baseline (1.77 = <10 min) to 30-day (2.77 = 10–20 min; $p < 0.001$) and 90-day (2.68 = 10–20 min; $p < 0.001$) assessments. The same pattern was observed for self-reported minutes of relaxation per day from baseline (1.84) to 30-day (2.92 = 10–20 min; $p < 0.001$) and 90-day (2.94 = 10–20 min; $p < 0.001$) follow-ups. No significant differences were found in participants' levels of confidence in guided imagery to help them quit smoking or perception of the logic of guided imagery for quitting smoking over time.

DISCUSSION

It is well established that unhealthy lifestyle behaviors, such as smoking, poor diet, and lack of physical activity, tend to cluster, and these factors are related to morbidity and mortality [84, 85]. There has been long-standing controversy as to the feasibility and effectiveness of interventions targeting multiple behaviors [86–88]. However, a growing body of literature has demonstrated the feasibility of these types of interventions [40, 89, 90] and suggests that positive changes can be made across multiple behaviors [39, 40, 91]. In addition, mHealth apps can be used effectively to increase the reach of behavioral interventions and disseminate evidence-based programs [40, 92, 93].

To our knowledge, our study is the first of its kind to deliver an imagery-based intervention targeting smoking, diet, and physical activity via a mobile app. Our study found that recruiting participants was easy, but retaining them was more challenging. We were able to recruit three times the number of participants originally planned during the recruitment phase. We planned to recruit only 50 participants, but almost 300 people downloaded and installed the app, and more than 150 women enrolled in the study. However, 52% of enrolled participants did not use the app as directed, and only 26% completed an exit survey to elucidate their lack of use. For those women who used the app, their use was associated with improvements in all three targeted health behaviors. Of the participants who used the app, 47% reported 7-day abstinence at the 90-day assessment, and continued smokers reported significant reductions in number of cigarettes smoked per day. In addition, use of the app was associated with an increase in leisure-time exercise, with participants reporting significantly higher amounts of moderate to strenuous exercise over the course of the study. The use of See Me Smoke-Free was also associated with modest gains in healthy eating, with increases in fruit consumption. Our results suggest that delivering guided imagery via an mHealth app is feasible, as only six participants reported technical issues with the app (and those were not specific to the guided imagery content of the app). This finding is tempered by the fact that we were unable to survey the majority of participants who did not use the app as directed.

The participants in this study had an average baseline weight of 170 lb, indicating a relatively heavy sample, which is not surprising given the clustering of smoking, poor diet, and sedentary behaviors. Overall, participants who used the app exhibited little weight change over the course of the study. It is possible that changes in physical activity, and perhaps improved dietary behaviors, may have mitigated weight gain among our participants. Although we anticipated that weight concern and body image would mediate cessation, in general, we found no significant decreases in these variables across time. These findings were unexpected, given the focus of the intervention on alleviating participants' concern about gaining weight and improving body image. It is possible that there was a direct effect of the physical activity component of our intervention or that our sample size was not sufficient to detect differences in these variables. A future efficacy study should be designed and adequately powered to detect differences in weight concern and body image.

The use of See Me Smoke-Free was associated with significant increases in adoption of daily guided imagery and other forms of relaxation. It is promising that the mHealth intervention resulted in sustained increase in the use of these techniques over time. At baseline, participants reported between 0 and 9 min of imagery or other forms of relaxation per day. At follow-up, participants reported 10–20 min spent on these techniques each day. These observations suggest that guided imagery usage may possibly offer women smokers a useful skill that could mediate emotional reactions associated with smoking. It is also possible that imagery use may mediate the relationship between body image and smoking cessation by impacting beliefs about smoking or emotional states such as anxiety. This possibility is supported by the observed relationship between the number of audio files completed and cessation at the 90-day follow-up. While our study was not designed or powered to test these effects, the present findings offer justification for continued research with larger sample sizes.

Limitations

The study suffered from several limitations. Foremost, similar to most mHealth studies [94–96], our study suffered from high attrition. We chose to drop participants who did not use the app. We required participants to use the app “most days for 30 days.” When participants did not use the app for 14 consecutive days, we contacted them to remind them to use the app as directed. If participants did not use the app, we tried to survey them as to their reasons for this lack of use. The fact that we dropped participants rather than including them in our analyses has implications for the interpretation of study results. Over half of the women who enrolled in the study withdrew or were dropped due to a variety of factors, including mobile phone or operating system-app incompatibility and difficulties with quitting. This degree of attrition, while typical of

technology-based interventions where there is little to no contact with study staff [94–96], warrants further investigation. In particular, it is important to understand whether and how the app addressed participants' needs for assistance in quitting smoking, controlling their weight, and improving self-efficacy in behavior change. In addition, more investigation is needed to determine what types of technical issues may have been faced when trying to use the app, as well as how to improve recruitment and retention of future participants without the benefit of face-to-face interactions. Improving understanding of factors related to mHealth engagement is particularly important given the potential, large “reach” of mHealth interventions to those individuals interested in health behavior change [97]. Although attrition was high, our baseline analyses indicated that there were no differences among those who remained in the study and those who dropped or withdrew. Through this study, we learned valuable lessons about how to improve processes and procedures for enrolling participants and create and maintain relationships between study staff and participants in order to minimize attrition in future studies. Retention and engagement are pressing issues in mHealth research, with many suggested techniques for increasing engagement, including more interactivity, changing content, and gamification [98–100]. Methods for improving study retention include more frequent contact (texting) throughout the study, using a more stringent enrollment process, and providing escalating incentives for each follow-up assessment [101–103]. A future randomized trial to test the efficacy of the app will use these new processes and procedures and an intent-to-treat statistical model.

Another limitation of this study is the lack of any measure of imagery ability, vividness, or control. This decision was made because we believed that generic measures of imagery ability, such as the Vividness of Mental Imagery Scale [104], would not appropriately measure the three behavioral targets in our study. While there are measures of motor or sport imagery ability [105], there are no published measures of imagery ability related to smoking cessation and dietary behavior. Laboratory-based measures of imagery ability were also not possible [106]. However, we were able to measure use of the imagery files, which was associated with positive smoking outcomes.

In addition, our measures of dietary intake lacked the precision necessary to adequately assess change over time. Future studies will use more sensitive tools for assessing change in dietary behaviors. Unfortunately, we were unable to use body mass index (BMI) as a metric due to loss of height data for a large percentage of the participants as a result of a technological issue. This problem will be corrected in future studies. Finally, the small sample sizes for analyses of change in confidence in quitting, concern about weight gain, and body image made it difficult to assess the impact of the intervention on these variables.

This study was designed to test only feasibility and potential impact and precluded testing the efficacy of

the See Me Smoke-Free app in comparison to a control condition. Here, we report associations between app use and selected target behaviors. Further research is needed to determine the efficacy of the app as a whole, how a multi-behavioral approach compares to a smoking-only intervention, and which components of the app are most effective.

Finally, we did not collect biomarkers related to tobacco use. We plan to biochemically validate tobacco abstinence via expired carbon monoxide in a future, large-scale randomized efficacy trial. Studies of mHealth interventions should consider methods by which to obtain biomarkers associated with health outcomes [107].

CONCLUSION

The recruitment methods for this study were very successful, resulting in three times as many participants as planned. Conversely, we experienced high attrition, which is common in eHealth interventions. However, the extended reach of this type of public health intervention may result in high overall impact. Different methods are needed to improve both engagement with the intervention and retention in the study. Even given the high attrition, the study's findings suggest that among those who used it, the See Me Smoke-Free app may increase women's rates of smoking abstinence and physical activity and decrease smoking among non-quitters. There were more modest dietary improvements. Participants who used the app increased their use of guided imagery, which was associated with smoking abstinence. Further research is needed to test the efficacy of the See Me Smoke-Free app, using improved design considerations, retention strategies, and statistical analyses.

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Compliance with ethical standards

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. This study was reviewed and approved by the University of Arizona Institutional Review Board.

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Statements: The findings reported have not been previously published, and this manuscript is not being simultaneously submitted elsewhere. Preliminary results of these data were presented at the 2016 Annual Meeting of the Society for Research on Nicotine and Tobacco but have not been published. The authors have full control of all primary data and agree to allow the journal to review their data if requested.

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