


Results of a Single Arm Pilot Study of a Mobile Messaging Intervention for Hookah Tobacco Cessation in Young Adults

Tobacco Use Insights
Volume 13: 1–7
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1179173X20915200



Darren Mays¹ , Lilianna Phan¹, Andrea C Johnson^{1,2},
Kenneth P Tercyak¹, Kylie Snow³, George Luta⁴,
Kathryn Rehberg¹ and Isaac Lipkus⁵

¹Cancer Prevention and Control Program, Georgetown Lombardi Comprehensive Cancer Center, Georgetown University Medical Center, Washington, DC, USA. ²Department of Prevention and Community Health, Milken Institute School of Public Health, The George Washington University, Washington, DC, USA. ³Department of Human Science, School of Nursing and Health Studies, Georgetown University, Washington, DC, USA. ⁴Department of Biostatistics, Bioinformatics, and Biomathematics, Georgetown University Medical Center, Washington, DC, USA. ⁵Duke University School of Nursing, Durham, NC, USA.

ABSTRACT

BACKGROUND: Hookah tobacco use is common among young adults. Unlike cigarette smoking, there is limited evidence on mobile (ie, mHealth) interventions to promote cessation.

OBJECTIVES: This pilot study tested the preliminary effects of mobile messaging for cessation in young adult hookah smokers.

METHODS: Young adults (N=20) aged 18 to 30 years who smoke hookah at least monthly and have done so at least once in the past 30 days received a 6-week mHealth multimedia messaging (text and images) intervention. Message scheduling (2 days/week × 6 weeks) was based on the literature. Content was developed iteratively by the study team and focused on health harms and addictiveness of hookah. Content was individually tailored by baseline hookah use frequency, risk beliefs, and responses to interactive text messages assessing participants' hookah tobacco use behavior and beliefs to maximize impact. Engagement was assessed during the intervention, and we examined effects on risk perceptions, risk beliefs, and risk appraisals, motivation to quit, and behavior change immediately post-intervention.

RESULTS: Participants responded to 11.5 (SD=0.69) of 12 text message prompts on average, endorsed high message receptivity (M=6.1, SD=0.93, range=1-7), and reported the messages were helpful (M=8.5, SD=1.5, range=1-10). There were significant ($P<.05$) increases in risk perceptions (d 's=0.22-0.88), risk appraisals ($d=0.49$), risk beliefs ($d=1.11$), and motivation to quit ($d=0.97$) post-intervention. Half of participants reported reducing frequency of hookah use (20%) or quitting completely (30%) by end of treatment.

CONCLUSIONS: These pilot results provide preliminary support for an mHealth messaging intervention about risks of hookah tobacco for promoting cessation. Rigorously examining the efficacy of this promising intervention is warranted.

KEYWORDS: Young adults, hookah, waterpipe, mobile, text messaging

RECEIVED: November 11, 2019. **ACCEPTED:** March 1, 2020.

TYPE: Original Research

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Research reported in this publication was supported by the National Cancer Institute of the National Institutes of Health under grant number CA217861. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Darren Mays, Cancer Prevention and Control Program, Lombardi Comprehensive Cancer Center, Georgetown University Medical Center, 3300 Whitehaven Street NW, Suite 4100, Washington, DC 20007, USA.
Email: dmm239@georgetown.edu

Introduction

Hookah (ie, waterpipe, shisha, narghile) is a commonly used tobacco product among U.S. young adults.¹ Hookah smoking poses risks of health harms (eg, cancer, lung disease), progression to more established use, addiction, and initiation of other combustible tobacco (eg, cigarette smoking).²⁻⁵ Young adults are a vulnerable population where nicotine addiction develops and transitions to regular tobacco use occur, and interventions are sorely needed to address hookah tobacco smoking in this group.^{3,5-8}

Young adults do not view hookah tobacco as harmful or addictive, and such risk beliefs are a major factor contributing to hookah use.⁹ Interventions aimed at changing these beliefs

by conveying risks of hookah use are one strategy that may motivate behavior change. Some evidence supports this approach, but research to date is limited to cross-sectional studies examining effects of messages delivered online.^{10,11} Evidence on how to optimally deliver and engage young adult hookah smokers with such messages is scarce.

Mobile phones are a promising channel to reach young adults with messages about risks of hookah tobacco use because virtually all U.S. young adults own a mobile phone with multimedia message service (MMS; that is, text and image) capabilities and nearly all use their device for text messaging.¹² Mobile messaging, or “mHealth,” interventions are effective for cigarette smoking cessation and they provide



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

the ability to implement interactive exchanges and to individually tailor content to enhance relevance and impact.¹³ Unlike cigarette smoking, no mHealth interventions exist to promote cessation in young adult hookah smokers. To address this research gap, this pilot study tested the preliminary effects of an innovative mHealth messaging intervention designed to promote hookah tobacco cessation in young adult hookah smokers.

Methods

Participants and procedures

Participants were recruited in 2018 through flyers in the local community, online ads, and by contacting participants from prior non-treatment research studies for tobacco use and other cancer risk behaviors. Eligible participants were young adults aged 18 to 30 years who were current hookah smokers (defined as smoking hookah at least once in the past 30 days and now smoking hookah at least monthly). Hookah tobacco smoking among young adults is often infrequent and social in nature.¹⁴ We chose these eligibility criteria based on the documented patterns of young adult hookah smoking in the literature¹⁴ in order to ensure the study sample included young people who smoke hookah tobacco with sufficient frequency for a cessation intervention. Participants had to have a personal mobile phone and agree to send and receive study text messages to take part in the study. Interested individuals completed eligibility screening questions online, and those eligible provided informed consent to complete study enrollment. Enrolled participants completed a baseline assessment online and their information was populated into the study mobile messaging system for intervention delivery. For this feasibility study, we assessed outcomes immediately post-intervention (ie, 6 weeks after baseline). Participants received a \$20 and a \$25 gift card for completing baseline and follow-up, respectively. All study participants provided informed consent and the study protocol was approved by the host institution's Institutional Review Board. The parent trial is registered at ClinicalTrials.gov (NCT03595280).

Messaging intervention

We developed a 6-week MMS intervention to convey the short- and long-term health harm, toxicant exposure, and addiction risks of hookah tobacco.¹⁵ We developed the program following recommended steps for creating mobile interventions.¹⁶ We created message content from models for health communication message development, existing hookah tobacco messaging research, and research on young adults' beliefs about hookah tobacco.^{10,17-19} We developed the message delivery sequence as a "story line" with message content (short- and long-term health harms, toxicant exposure, addictiveness) arranged to form a logical sequence over time.¹⁶ We aligned the 12 message themes with common misperceptions about risks

of hookah tobacco use in young adults.¹⁹ To facilitate message tailoring, we categorized participants' responses to baseline risk belief items as "Low" indicating they do not believe hookah to be risky (response 1-4) or "High" risk beliefs that hookah has greater risks (response 5-7), and aligned the message content to low and high risk beliefs corresponding to each theme.¹⁵ Messages conveyed the risks of hookah tobacco through text and visual imagery (ie, MMS) with images selected to convey the core risk communicated in text. We pretested message content through an iterative process including (1) collecting quantitative and qualitative feedback on draft message content from an initial sample of 151 young adult hookah smokers, (2) refining the content based on feedback from this initial sample, (3) assessing quantitative and qualitative responses to updated content in an independent sample of 156 young adult hookah smokers, and (4) finalizing the content for improvement based on their feedback.¹⁵

Participants interacted with the messaging system by responding to a text message prompt delivered to their personal mobile phone on 2 days each week during the 6-week intervention exposure period. Although text messaging interventions for behaviors such as cigarette smoking cessation involve intensive message delivery¹³ (eg, multiple messages a day), there is no direct evidence published on the delivery of mHealth interventions for hookah tobacco cessation. We chose to deliver messages on 2 days each week and the total duration of 6 weeks of message exposure based on evidence of typical patterns of young adult hookah smoking (ie, predominantly non-daily use)^{3,14} and recommendations for mobile messaging behavior change programs to ensure sufficient exposure and avoid burn-out over time.²⁰⁻²²

We designed prompts to engage participants in a 2-way, interactive exchange by posing questions about their hookah use behavior or their beliefs about risks. Examples of prompts include "Have you thought about how smoking hookah can harm your health? Reply with yes or no" and "Have you smoked hookah in the past week? Let us know, even if it was a puff or two. Reply with yes or no." After responding to the prompts, participants received individually tailored MMS risk message content in return. Message content was individually tailored based on data collected at baseline and responses to the text message prompts using an if-then algorithm. Specifically, we tailored each message to 3 variables: (1) baseline hookah tobacco use frequency (ie, frequent, infrequent); (2) baseline risk beliefs (ie, high, low) corresponding to each message; and (3) responses to the interactive text message prompt delivered immediately before the MMS message. Prompts and message content were spaced throughout each week in the intervention exposure such that the first message day occurred early in the week (eg, Tuesday) and the second occurred later in the week (eg, Friday) prior to the weekend. The MMS prompts and risk messages were delivered using Mobile Commons, a mobile messaging engagement platform that provides 2-way MMS

and text communication support and the ability to implement algorithms to facilitate message tailoring.⁹

Measures

Demographic characteristics. We assessed demographic characteristics at baseline including age, sex, race, Hispanic ethnicity, college enrollment status, educational attainment, employment status, annual household income, and subjective financial status.¹

Cigarette smoking and other tobacco use. We measured cigarette smoking at baseline with 2 valid questions identifying those who have smoked ≥ 100 cigarettes in their lifetime and now smoke cigarettes “every day” or “some days” as cigarette smokers.¹ At baseline we also asked participants whether they had used large cigars, little cigars/cigarillos, smokeless tobacco, and electronic cigarettes in the past 30 days.¹

Message response and engagement. We measured message receptivity at follow-up with a 14-item measure assessing participants’ agreement with statements about the messages.²³ Example items include the following: The information was believable; The information was important to me; Overall, I was satisfied with the information. Responses ranged from 1 = Strongly Disagree to 7 = Strongly Agree and were summed and averaged for each participant (Cronbach’s $\alpha = 0.95$). We measured message engagement as the number of text message prompts participants responded to during the 6-week period out of 12 possible. On the final day of the message exposure period, we also asked participants to report how helpful the messages were via their response to a text message on a 10-point scale (1 = not at all helpful, 10 = very helpful).

Hookah tobacco risk beliefs. We assessed hookah tobacco risk beliefs, a measure of endorsement of specific health and addiction risks of hookah tobacco use, at baseline and at follow-up using 12 items.¹⁹ Responses ranged from 1 = strongly agree to 7 = strongly disagree and some items were reverse coded for consistent directionality. As noted above, to facilitate tailoring the text messages using baseline data, we categorized risk beliefs as “low” (1-4) or “high” (5-7) indicating greater risk beliefs.¹⁵ As these risk belief categories formed the basis of the messaging intervention themes and tailoring, we analyzed change in the proportion of participants endorsing high-risk beliefs at each time point as well as change in average risk belief score where higher values indicate stronger risk beliefs (baseline $\alpha = 0.89$; follow-up $\alpha = 0.81$).

Perceived relative harm and addictiveness of hookah tobacco. We assessed perceived harm of hookah tobacco relative to cigarettes at baseline and follow-up with a single item, “Compared to regular cigarettes, how harmful do you think smoking hookah tobacco is?” Responses were on a 5-point

scale (1 = much less harmful; 2 = less harmful; 3 = as harmful; 4 = more harmful; 5 = much more harmful).^{10,11} We measured perceived addictiveness of hookah tobacco relative to cigarettes at baseline and follow-up with a similar item.^{10,11}

Hookah tobacco risk appraisals. We assessed hookah tobacco risk appraisals at baseline and follow-up using 4 valid items.^{10,11} We measured perceived risk of harm from hookah tobacco smoking by asking “What do you think is your chance of getting a serious smoking-related disease, such as cancer, lung disease, or heart disease, if you continue to smoke hookah tobacco?” Responses were based on a 1 (no chance) to 7 (certain to happen) scale. We assessed worry about harms of hookah tobacco by asking “How much do you worry that your health is being hurt by your hookah tobacco smoking?” Responses were on a 1 (not at all) to 7 (very much) scale. We assessed perceived risk of addiction to hookah tobacco by asking “What do you think is your chance of becoming addicted to nicotine in tobacco from hookah tobacco if you continue to smoke?” Responses were based on a 1 (no chance) to 7 (certain to happen) scale. We measured worry about addiction by asking “How worried are you about becoming addicted to nicotine in hookah of you continue to smoke it?” Responses were based on a 1 (not at all) to 7 (very much) scale. We summed and averaged responses to the risk appraisal items at each time point (baseline $\alpha = 0.62$, follow-up $\alpha = 0.87$).¹⁹

Motivation to quit. We measured motivation to quit smoking hookah tobacco at baseline and among those who did not report quitting at follow-up using a single item with a 1 to 7 response scale where higher values indicate stronger motivation.^{11,19}

Hookah tobacco use. At baseline and follow-up participants reported frequency of hookah tobacco smoking based on valid items.^{10,11} First, they responded to the question “On how many days of the past 30 days did you smoke tobacco in a hookah?” Response choices ranged from 0 to 30. Second, participants responded to the question “Which of the following best describes your hookah tobacco smoking? Usually I smoke hookah . . .” (1) Less than monthly (occasionally, but not every month); (2) Monthly (at least once a month, but less than weekly); (3) Weekly (at least once a week, but less than daily); (4) Daily (at least once a day, or on most days of the month). At follow-up, among participants who reported they did not smoke hookah tobacco in the past month, we assessed whether they had quit smoking hookah tobacco completely using a single item.¹ We created a variable indicating infrequent (monthly) and frequent (weekly or daily) hookah smoking, and using data at both time points we characterized whether participants increased use (eg, from monthly to weekly use), decreased use (eg, from weekly to monthly use), or reported quitting smoking hookah tobacco completely.¹¹

Statistical analysis

We used descriptive statistics to characterize the sample and paired sample *t*-tests to examine change in measures administered at baseline and follow-up, and we calculated Cohen's *d* as a measure of effect size. For risk belief items corresponding to message themes and the message tailoring process, we also examined change in the proportion of participants indicating low- and high-risk beliefs from baseline to follow-up using McNemar's test. As we only assessed message response and engagement variables at follow-up only, we analyzed these descriptively. We performed all statistical analyses using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Participants

Twenty-seven participants responded to recruitment materials and 20 (74%) were eligible to participate. All those who were ineligible had not smoked hookah in the past 30 days and/or did not report smoking hookah at least monthly. The sources of recruitment for enrolled participants were prior non-treatment studies ($n=17, 85\%$), flyers ($n=1, 5\%$), and through a friend ($n=2, 10\%$). All eligible, enrolled participants completed study procedures. On average, participants were 24.0 (median = 23.5, $SD=3.5$, range = 18-29) years of age, and half ($n=10, 50\%$) were female. At baseline, 9 participants (45%) reported smoking hookah tobacco monthly, 8 (40%) weekly, and 3 (15%) daily. Table 1 displays additional characteristics of participants at baseline.

Message response and engagement

Participants reported high message receptivity following the exposure (mean = 6.1, median = 6.2, $SD=0.9$, range = 4.4-7.0) and they were highly engaged responding to an average of 11.5 (median = 12, $SD=0.7$, range = 10-12) of 12 text message prompts. At the conclusion of the intervention, participants indicated on average the messages were helpful (mean = 8.5, median = 9.0, $SD=1.5$, range = 6-10).

Hookah tobacco risk beliefs

Table 2 displays the proportion of participants indicating high risks of hookah tobacco for individual risk beliefs assessed at baseline and follow-up. The increase in this proportion was statistically significant for 4 beliefs assessed ($P<.05$) and the increase approached significance for 2 other beliefs ($P=.057$, $P=.056$). The average risk belief score increased significantly from baseline (mean = 4.2, median = 2.2, $SD=1.1$, range = 2.3-6.0) to follow-up (mean = 5.2, median = 5.0, $SD=0.9$, range = 3.2-6.8; $P<.001$, Cohen's $d=1.11$).

Hookah tobacco risk perceptions and risk appraisals

Perceived harm relative to cigarette smoking increased significantly from baseline (mean = 2.6, median = 3.0, $SD=0.93$,

Table 1. Sample characteristics (N=20).

	MEAN (MEDIAN, SD)	N (%)
Age (range, 18-29)	24.0 (23.5, 3.5)	
Sex		
Male		10 (50)
Female		10 (50)
Race		
Black/African American		8 (40)
White		9 (45)
Other Race		3 (15)
Ethnicity		
Hispanic		0
Non-Hispanic		20 (100)
College enrollment status		
College student		9 (45)
Non-student		11 (55)
Education		
\leq Some college		11 (55)
\geq College degree		9 (45)
Employment		
Not full-time employed		11 (55)
Full-time employed		9 (45)
Annual household income		
\leq \$50,000		10 (50)
$>$ \$50,000		10 (50)
Subjective financial status		
Don't meet or just meet basic expenses		6 (30)
Meet needs with a little left		8 (40)
Live comfortably		6 (30)
Hookah tobacco smoking		
Frequency of hookah use		
Monthly		9 (45)
Weekly		8 (40)
Daily		3 (15)
Past month hookah use frequency (range, 1-20)	7.6 (5.0, 6.3)	
Cigarette smoking status		
Smoker		9 (45)
Non-smoker		11 (55)

(Continued)

Table 1. (Continued)

	MEAN (MEDIAN, SD)	N (%)
Other tobacco product use		
Large cigars		8 (40)
Little cigars		7 (35)
Smokeless tobacco		7 (35)
Electronic cigarettes		9 (45)

range = 1.0-4.0) to follow-up (mean = 3.6, median = 3.5, SD = 0.8, range = 2.0-5.0; $P < .001$, Cohen's $d = 0.88$). Similarly, perceived relative addictiveness of hookah increased from baseline (mean = 2.1, median = 2.0, SD = 0.9, range = 1.0-3.0) to follow-up (mean = 2.7, median = 3.0, SD = 0.9, range = 1.0-4.0; $P = .008$, Cohen's $d = 0.23$). Hookah tobacco risk appraisals (ie, perceived risk and worry about risks) increased significantly from baseline (mean = 3.9, median = 3.9, SD = 1.0, range = 1.5-5.0) to follow-up (mean = 4.3, median = 4.4, SD = 1.4, range = 1.8-7.0; $P = .041$, Cohen's $d = 0.49$) as well.

Motivation to quit and hookah tobacco use

Motivation to quit smoking hookah increased significantly from baseline (mean = 2.5, median = 2.5, SD = 1.7, range = 1.0-5.0) to follow-up (mean = 4.4, median = 4.5, SD = 1.9, range = 2.0-7.0; $P = .003$, Cohen's $d = 0.97$) among those who had not reported quitting at follow-up. At follow-up, 6 participants (30%) reported quitting smoking hookah tobacco completely, 4 participants (20%) decreased frequency of smoking hookah, and the remaining 10 participants (50%) reported no change in frequency of smoking hookah. Among those who reported quitting smoking hookah tobacco at follow-up, 3 (50%) were frequent users (ie, daily or weekly) and 3 (50%) were infrequent users (ie, monthly) at baseline. Among those who reported reducing frequency of hookah tobacco smoking, all ($n = 4$, 100%) were frequent users at baseline. Among those reporting no change in the frequency of hookah smoking at follow-up, 4 (40%) were frequent users at baseline and 6 (60%) infrequent users at baseline.

Discussion

Results of this pilot study indicate a mHealth messaging intervention conveying risks of hookah tobacco use was well received among young adult hookah smokers. Message receptivity was high relative to similar studies examining this measure in comparable young adult samples following message exposure.^{11,18} Participants responded to nearly all text message prompts during the exposure period and at the conclusion of the intervention they indicated message content was helpful. All participants completed study procedures, including the intervention and follow-up assessment. Overall, these findings support the

feasibility of implementing a mHealth messaging intervention for young adult hookah tobacco smokers.

We observed changes in measures of risk perceptions and risk appraisals that were targets of the MMS intervention. Perceived harm and addictiveness relative to cigarettes and risk appraisals, a measure reflecting perceived likelihood and worry about harm and addictiveness, increased significantly from baseline to follow-up. In addition, we observed significant increases in the proportion of participants endorsing some discrete hookah risk beliefs that were targeted by individual messages and a significant increase in the risk belief score reflecting the summary of these individual beliefs. Notably, however, there was no significant increase in the proportion of participants endorsing high-risk beliefs for seven of those assessed. These constructs have been shown to be associated with behavior change in response to behavioral interventions in prior research, and our findings are consistent with prior studies examining the effects of risk messages for hookah tobacco use.^{10,11,18,19,24} Prior research testing the effects of hookah tobacco risk messages demonstrates such communication can increase risk appraisals and motivation to quit in young adult hookah smokers.^{10,11} We extend this research by demonstrating messages delivered prospectively and via a mobile platform can affect similar outcomes with the potential to produce larger effects. However, important questions that stem from our findings require continued examination in future studies. In particular, continued examination of general perceived risk (eg, risk appraisals, risk perceptions) and discrete risk beliefs in response to the intervention with a larger sample and longer follow-up duration will be informative to better understand how the intervention affects beliefs about the risks of hookah tobacco and what beliefs may be important mediators of behavior change.

We also observed changes in outcomes related to hookah tobacco use behavior that provide preliminary indicating that the intervention may affect target behavioral outcomes. Motivation to quit smoking hookah increased significantly following the intervention and half of participants reported either decreasing the frequency of hookah tobacco smoking or quitting completely following the intervention. These preliminary findings are a promising indication that our MMS intervention has potential to produce meaningful change in hookah tobacco use behavior among young adults, but they require verification in future studies that rigorously assess intervention efficacy.

There is very limited research on interventions for hookah tobacco smoking cessation for young adults.²⁵ The study findings provide preliminary evidence that a mHealth intervention delivering carefully designed, individually tailored MMS messaging about the risks of hookah tobacco is a promising intervention. However, the results should be interpreted based on limitations of the study. This was a single arm pilot with a convenience sample of 20 young adult hookah smokers. More rigorous assessment of the intervention relative to a control group is necessary to test intervention efficacy. We assessed outcomes immediately following the intervention and longer follow-up

Table 2. Change in hookah tobacco risk beliefs assessed at baseline and follow-up.

RISK BELIEF	N (%) ENDORSEMENT BASELINE	N (%) ENDORSEMENT FOLLOW-UP	P
I don't smoke enough hookah tobacco to be hurting my health.	8 (40)	14 (70)	.057
Smoking hookah once or twice a month is not harmful.	9 (45)	13 (65)	.102
When I smoke hookah tobacco, I inhale cancer causing chemicals.	11 (55)	18 (90)	.020
The water in the hookah filters out most of the harmful chemicals from the smoke.	9 (45)	16 (80)	.008
The health risks of hookah tobacco smoking are over-exaggerated.	9 (45)	15 (75)	.056
Hookah tobacco smoking can cause severe health consequences.	16 (80)	18 (90)	.318
I will have quit smoking hookah tobacco long before I need to worry about getting health problems.	5 (25)	7 (35)	.317
Hookah tobacco does not have enough nicotine to cause addiction.	9 (45)	16 (80)	.020
Smoking hookah for an hour or two in such settings as bars, cafes, and lounges is not harmful to my health.	7 (35)	17 (85)	.004
Sharing the hookah mouthpiece with other smokers can lead to infections.	14 (70)	16 (80)	.414
The burning of the charcoal to heat the hookah tobacco produces harmful chemicals.	11 (55)	15 (75)	.157
Smoking hookah tobacco once or twice a month can lead to addiction.	7 (35)	8 (40)	.655

Responses to risk belief items ranged from 1 = strongly agree to 7 = strongly disagree. Responses were categorized as "low" (1-4) indicating they did not believe hookah tobacco use to be risky or "high" (5-7) indicating greater risk beliefs. Percentages displayed reflect the proportion of participants endorsing high risk beliefs at each time point.

is needed to assess the duration of intervention effects. We dichotomized analyses of item-level data for the hookah tobacco risk beliefs to align with how these beliefs were used in the intervention tailoring. In the future, it will be important to examine these in a more robust way, such as item-level changes of mean beliefs corresponding to each message. We relied on valid, self-report measures of hookah tobacco use behaviors and cessation at follow-up. To our knowledge, there is no validated biochemical measure to confirm hookah tobacco use and cessation because those that do exist (eg, nicotine-based biomarkers, carbon monoxide) are confounded by other tobacco and nicotine product use. This is a critical issue to address in future hookah tobacco intervention research. In our sample, and in young adults nationally, there is substantial overlap between hookah smoking and other tobacco and nicotine product use including cigarette smoking.¹⁴ In the future it will be important to examine the effects of co-use of other tobacco products on intervention outcomes, and if and how interventions targeting a single product such as hookah tobacco smoking affect other tobacco use behavior. Engagement with the intervention was high overall and message content was well-received. Future investigations of how factors such as engagement and receptivity to content relate to behavior change outcomes will advance our understanding of how this intervention approach can be optimized by, for example, adjusting the duration, dose, or frequency of message exposure.

Despite these limitations, this study is one of the first to demonstrate preliminary effects on intended outcomes for a mHealth messaging intervention designed to motivate cessation in young adult hookah smokers. Given the extremely limited evidence on interventions for hookah tobacco use in this priority group, these data indicate our mHealth intervention delivering messages conveying the risks of hookah use is a promising strategy for promoting cessation. These pilot results require confirmation in a larger, rigorous investigation examining intervention efficacy relative to a control group.

Author Contributions

DM, KT, and IL conceptualized the study and secured funding for the research. DM, AJ, and GL analyzed the data. DM and LP prepared the initial draft of the manuscript. All authors contributed substantively to interpretation of the findings, revising the manuscript, and approved final manuscript for publication.

ORCID iD

Darren Mays  <https://orcid.org/0000-0002-6605-0743>

REFERENCES

- Hu SS. Tobacco product use among adults—United States, 2013–2014. *MMWR Morb Mortal Wkly Rep.* 2016;65:685–691. doi:10.15585/mmwr.mm6527a1.
- El-Zaatari ZM, Chami HA, Zaatari GS. Health effects associated with water-pipe smoking. *Tob Contr.* 2015;24:i31–i43. doi:10.1136/tobaccocontrol-2014-051908.

3. Sidani JE, Shensa A, Naidu MR, Yabes JG, Primack BA. Initiation, progression, and sustained waterpipe use: a nationally representative longitudinal study of U.S. *Cancer Epidemiol Biomarkers Prev.* 2017;26:748-755. doi:10.1158/1055-9965.EPI-16-0687-T.
4. Sidani JE, Shensa A, Shiffman S, Switzer GE, Primack BA. Behavioral associations with waterpipe tobacco smoking dependence among U.S. young adults. *Addiction.* 2016;111:351-359. doi:10.1111/add.13163.
5. Shepardson RL, Hustad JTP. Hookah tobacco smoking during the transition to college: prevalence of other substance use and predictors of initiation. *Nicotine Tob Res.* 2016;18:763-769. doi:10.1093/ntr/ntv170.
6. Sussman S, Arnett JJ. Emerging adulthood: developmental period facilitative of the addictions. *Eval Health Prof.* 2014;37:147-155. doi:10.1177/0163278714521812.
7. Primack BA, Freedman-Doan P, Sidani JE, et al. Sustained waterpipe tobacco smoking and trends over time. *Am J Prev Med.* 2015;49:859-867. doi:10.1016/j.amepre.2015.06.030.
8. Hair E, Rath JM, Pitzer L, et al. Trajectories of hookah use: harm perceptions from youth to young adulthood. *Am J Health Behav.* 2017;41:240-247. doi:10.5993/AJHB.41.3.3.
9. Akl EA, Jawad M, Lam WY, Co CN, Obeid R, Irani J. Motives, beliefs and attitudes towards waterpipe tobacco smoking: a systematic review. *Harm Reduct J.* 2013;10:12. doi:10.1186/1477-7517-10-12.
10. Lipkus IM, Eissenberg T, Schwartz-Bloom RD, Prokhorov AV, Levy J. Affecting perceptions of harm and addiction among college waterpipe tobacco smokers. *Nicotine Tob Res.* 2011;13:599-610. doi:10.1093/ntr/ntn049.
11. Mays D, Tercyak KP, Lipkus IM. The effects of brief waterpipe tobacco use harm and addiction education messages among young adult waterpipe tobacco users. *Nicotine Tob Res.* 2016;18:777-784. doi:10.1093/ntr/ntv223.
12. Pew Research Center. U.S. Smartphone use in 2015. Update April 2015. <https://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/>. Accessed May 20, 2019.
13. Spohr SA, Nandy R, Gandhiraj D, Vemulapalli A, Anne S, Walters ST. Efficacy of SMS text message interventions for smoking cessation: a meta-analysis. *J Subst Abuse Treat.* 2015;56:1-10. doi:10.1016/j.jsat.2015.01.011.
14. Robinson JN, Wang B, Jackson KJ, Donaldson EA, Ryant CA. Characteristics of hookah tobacco smoking sessions and correlates of use frequency among US adults: findings from Wave 1 of the Population Assessment of Tobacco and Health (PATH) Study. *Nicotine Tob Res.* 2018;20:731-740. doi:10.1093/ntr/ntx060.
15. Johnson AC, Lipkus I, Tercyak KP, et al. Development and pretesting of risk-based mobile multimedia message content for young adult hookah use. *Health Educ Behav.* 2019;46:97-105. doi:10.1177/1090198119874841.
16. Abroms LC, Whittaker R, Free C, Mendel Van Alstyne J, Schindler-Ruwisch JM. Developing and pretesting a text messaging program for health behavior change: recommended steps. *JMIR Mhealth Uhealth.* 2015;3:e107. doi:10.2196/mhealth.4917.
17. Hornik RC, Volinsky AC, Mannis S, et al. Validating the Hornik & Woolf approach to choosing media campaign themes: do promising beliefs predict behavior change in a longitudinal study? *Commun Meth Measure.* 2019;13:60-68. doi:10.1080/19312458.2018.1515902.
18. Lipkus IM, Mays DP, P Tercyak K. Characterizing young adults' susceptibility to waterpipe tobacco use and their reactions to messages about product harms and addictiveness. *Nicotine Tob Res.* 2017;19:1216-1223. doi:10.1093/ntr/ntw251.
19. Lipkus IM, Mays D. Comparing harm beliefs and risk perceptions among young adult waterpipe tobacco smokers and nonsmokers: implications for cessation and prevention. *Addict Behav Rep.* 2018;7:103-110. doi:10.1016/j.abrep.2018.03.003.
20. Evans W, Nielsen PE, Szekely DR, et al. Dose-response effects of the text4baby mobile health program: randomized controlled trial. *JMIR Mhealth Uhealth.* 2015;3:e12. doi:10.2196/mhealth.3909.
21. Naughton F, Jamison J, Boase S, et al. Randomized controlled trial to assess the short-term effectiveness of tailored web- and text-based facilitation of smoking cessation in primary care (iQuit in practice). *Addiction.* 2014;109:1184-1193. doi:10.1111/add.12556.
22. Free C, Phillips G, Galli L, et al. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS Med.* 2013;10:e1001362. doi:10.1371/journal.pmed.1001362.
23. Zhao X, Nan X. Influence of self-affirmation on responses to gain- versus loss-framed antismoking messages. *Hum Commun Res.* 2010;36:493-511. doi:10.1111/j.1468-2958.2010.01385.x.
24. Sheeran P, Harris PR, Epton T. Does heightening risk appraisals change people's intentions and behavior? a meta-analysis of experimental studies. *Psychol Bull.* 2014;140:511-543. doi:10.1037/a0033065.
25. Jawad M, Jawad S, Waziry RK, Ballout RA, Akl EA. Interventions for waterpipe tobacco smoking prevention and cessation: a systematic review. *Sci Rep.* 2016;6:25872. doi:10.1038/srep25872.