Tailored Mobile Messaging Intervention for Waterpipe Tobacco Cessation in Young Adults: A Randomized Trial

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See also Busch et al., p. 1567.

Objectives. To test a tailored mobile health (i.e., mHealth) intervention for waterpipe tobacco cessation in young adults.

Methods. From 2018 to 2020 at 2 US sites, we conducted a randomized trial with 349 waterpipe tobacco smokers aged 18 to 30 years randomized to control (no intervention), untailored, or tailored intervention arms. Intervention arms received a 6-week mHealth intervention conveying risks of waterpipe tobacco through text and images and strategies to enhance motivation and support quitting. The tailored intervention was personalized to baseline measures and intervention text message responses. Risk appraisals, motivation to quit, waterpipe smoking frequency, and cessation were assessed at 6 weeks, 3 months, and 6 months.

Results. At 6 months, cessation was higher in the tailored (49%) than the control arm (29%; odds ratio = 2.4; 95% confidence interval = 1.3, 4.2) and smoking frequency was lower in the tailored (mean = 3.5 days) than the control arm (mean = 4.3 days; $P = .006$). At interim follow-ups, significant differences in other outcomes favored the tailored intervention.

Conclusions. Tailored mobile messaging can help young adult waterpipe tobacco smokers quit. This scalable intervention is poised for population implementation. (*Am J Public Health*. 2021;111(9):1686–1695. https://doi.org/10.2105/AJPH.2021.306389)

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Waterpipe (i.e., hookah) smoking is a method of tobacco use in which tobacco (usually sweetened or flavored) is heated with charcoal, smoke passes through water, and the smoke is inhaled by the user. Waterpipe tobacco smoking poses risks of health harm (e.g., cancer, cardiovascular disease, respiratory disease) and addictiveness, and is understudied relative to other forms of tobacco use.[1–8] Among US adults, the prevalence of waterpipe tobacco smoking is low overall, but it is more common in certain subgroups (e.g., some racial/ethnic and sexual minorities) and most common among young adults aged 18 to 30 years.[9–12] In the Population Assessment of Tobacco and Health (PATH) Study (wave 1, total n = 45 971), 11% of young adults were past-30-day waterpipe tobacco smokers, and young adults comprised 78% and 88% of adults who smoked waterpipe tobacco daily or weekly and monthly, respectively.[10] Prospective PATH data show that although most young adults who smoke waterpipe tobacco do so intermittently (i.e., nondaily), many sustain use over time.[13] Young adults' waterpipe tobacco smoking is influenced by multiple factors, including appealing flavors, marketing, and use in social settings.[14,15] Importantly, young adults' misperceptions that waterpipe tobacco is not harmful or addictive are major factors contributing to waterpipe tobacco smoking.[14–19] Young adults also have low motivation to quit waterpipe tobacco smoking and believe quitting is easy, yet many develop dependence symptoms and have difficulty quitting.[6,20]

There is very limited research on waterpipe tobacco smoking cessation interventions in young adults. A 2015 Cochrane review found only 3 intervention studies, 1 of which focused on young adults.[21] Subsequent reviews included additional intervention studies,[22,23] but all found limited evidence for cessation interventions targeting young people. Furthermore, many interventions studied to date have low appeal and are less likely to benefit young adults because they focus on exclusive, daily waterpipe tobacco smokers.[21–23] The growth in young adult waterpipe use, associations with cigarette smoking,[24] and research gaps have produced calls to develop interventions addressing use patterns (i.e., nondaily smoking) and underlying misperceptions about risks in young adults.[21,23]

A recent study piloted a personally tailored, mobile health (i.e., mHealth) messaging cessation intervention for young adult waterpipe smokers.[25] Results demonstrated acceptability and feasibility of the intervention and preliminary effects on behavioral outcomes.[25] mHealth is a promising strategy for waterpipe tobacco cessation interventions among young adults for several reasons. First, most US young adults own a mobile phone and use their phone for text messaging,[26,27] and they are receptive to mHealth interventions.[26,28] This positions mHealth interventions for high reach in the target population. Second, mobile messaging systems can deliver messages with text and visual imagery (i.e., multimedia message service; MMS); this approach can enhance the effects of tobacco messaging.[29] Third, mHealth interventions are scalable with the potential to be freely available to the US population. Finally, mobile messaging systems can also deliver interventions interactively and tailor content to individual characteristics. Tailored messaging increased the effects of online and mHealth interventions for cigarette smoking cessation in previous studies.[30–32]

Pilot research[25] supports the use of personally tailored mHealth interventions for waterpipe tobacco cessation, but they have not been tested rigorously. The goal of this study was to test the efficacy of an interactive mHealth cessation intervention in young adult waterpipe tobacco smokers and examine if a personally tailored intervention had added effects compared with an untailored intervention. The primary outcomes were risk appraisals (i.e., perceived risk, worry), cessation, waterpipe tobacco smoking frequency, and motivation to quit at 6 months. We also report results of secondary outcomes at interim time points (6 weeks, 3 months) based on recommendations for tobacco cessation trials.[33]

METHODS

This study was a 2-site, 3-arm, parallel group randomized trial. All participants provided informed consent, and the participating institutions' institutional review boards approved all procedures.

Participants

From 2018 to 2020, we recruited participants from the community at 2 academic medical centers in the US Mid-Atlantic region. Recruitment advertisements sought young adults for a study about waterpipe tobacco beliefs and behavior and directed interested individuals to a Web site with study details and a link to an eligibility screener. Eligible participants were young adults aged 18 to 30 years who reported smoking waterpipe tobacco in the past month and on at least a monthly basis. We chose these behavioral eligibility criteria based on young adults' waterpipe tobacco smoking patterns and previous pilot work to ensure participants smoked waterpipe tobacco with sufficient frequency for a cessation intervention.[10,25] Eligible participants also had to be able to complete study procedures in English and agree to use a personal mobile phone to send and receive study text messages. There were no other explicit exclusion criteria (e.g., for other medical conditions or alcohol or substance use).

Procedures

Eligible individuals provided informed consent online, completed an online baseline assessment, and received basic information on the risks of waterpipe tobacco smoking.[34,35] Participants were randomized to 1 of the 3 trial arms: control, untailored intervention, or tailored intervention. Participants completed follow-ups online 6 weeks, 3 months, and 6 months after baseline. Participants received incentives for completing study milestones ($20 at baseline, $25 at 6 weeks, $25 at 3 months, and $30 at 6 months).

Randomization

We randomized participants in a 1:1:1 ratio to the 3 trial arms; the randomization sequence was prepared in blocks by a statistician not involved in the trial. We stratified randomization by whether participants reported infrequent (i.e., monthly) or frequent (i.e., daily or weekly) waterpipe tobacco smoking at baseline to ensure balance by the trial arms.

Control Arm

Participants in the control arm received no intervention; they completed assessments only.

Intervention Arms

The intervention was a 6-week mobile messaging intervention. Descriptions of the message content development, pretesting, and the intervention pilot were published previously.[34,36] Messages were delivered on 2 days each week for 6 weeks, a frequency and duration based on patterns of young adult waterpipe tobacco smoking[10] and recommendations for mHealth interventions.[37–39] The content was scheduled for all participants so the first message day occurred early in the week (Tuesday) and the second occurred before the weekend (Friday).

We developed the intervention based on recommendations for mobile interventions,[40] recommendations for waterpipe tobacco interventions,[41] and research on young adults' waterpipe tobacco beliefs and behavior.[35,42–45] The message content communicated the short- and long-term health harms, toxicant exposure, and addictiveness of waterpipe tobacco use.[40] The content was sequenced to avoid repetition and introduce new information over time.

We developed the 12 message themes to align with misperceptions about risks of waterpipe tobacco use in young adults from previous research.[44] Messages conveyed risks of waterpipe tobacco through text and visual imagery (i.e., MMS) with images selected to convey the core risk communicated in text.[34,36] The intervention was designed to enhance motivation to quit by building behavioral skills, increasing confidence, and providing strategies for behavior change.[46–48] Over 6 weeks, this progressed from thinking about risks to planning to avoid waterpipe tobacco smoking, incorporating behavioral substitutes, and making a plan to quit.

The first day was an introductory message preparing participants to start. Each message day thereafter, participants first responded to a text message prompt that engaged participants by posing questions about waterpipe tobacco use or beliefs about risks. After responding to the prompts, participants received the MMS risk message content.

In the untailored intervention arm, all participants received the same prompts and message content. In the tailored intervention arm, we personalized the MMS message content to participants' baseline waterpipe tobacco smoking frequency, baseline risk beliefs, and responses to the prompts during the intervention. For waterpipe tobacco smoking frequency, we categorized participants as infrequent (i.e., monthly) or frequent (i.e., daily or weekly) smokers at baseline. For risk beliefs, we used a 12-item measure of beliefs about the health harms and addictiveness of waterpipe tobacco at baseline to tailor the messages.[44] Each risk belief aligned with 1 of the messages, and we categorized participants' responses to each baseline risk belief item as "low" indicating they do not believe waterpipe tobacco smoking to be risky or "high" risk beliefs that waterpipe smoking has greater risks for tailoring.[36] We also tailored the content to participants' responses to the text message prompts, such as whether they reported smoking waterpipe tobacco. Example intervention messages are provided in Table A (available as a supplement to the online version of this article at http://www.ajph.org).

Measures

At baseline, we assessed age, gender, race, Hispanic ethnicity, educational attainment, employment status, and household income.[49] We measured cigarette smoking at baseline, defining cigarette smokers as those who have smoked at least 100 cigarettes in their lifetime and now smoke cigarettes every day or some days.[49] We assessed past-30-day use of other tobacco (large cigars, little cigars, cigarillos, smokeless tobacco, electronic cigarettes)[49] and summarized responses as any other tobacco use in the past 30 days (yes or no).[35] We also captured number of days in the past 30 days drinking alcohol.[49]

We assessed waterpipe tobacco risk appraisals at all time points using 4 items—2 for harms and 2 for addiction.[34,35,43] Perceived risk of harms (i.e., chance of disease) from smoking waterpipe tobacco was based on a 1 (no chance) to 7 (certain to happen) scale. Worry about harms was also measured on a 1 (not at all) to 7 (very much) scale. We used 2 similar items to measure perceived risk of addiction (1–7 scale) and worry about addiction (1–7 scale). Based on previous studies,[34,35,43] we created a summary risk appraisals outcome by averaging responses to the 4 items at each time point (Cronbach's $\alpha = .72$ at baseline, .76 at 6 weeks, .75 at 3 months, and .80 at 6 months). We also analyzed each item separately, the results of which are shown in Table B (available as a supplement to the online version of this article at http://www.ajph.org).

At baseline, we assessed waterpipe tobacco use frequency and dependence. We asked whether participants usually smoked waterpipe tobacco monthly, weekly, or daily and

categorized participants as infrequent (i.e., monthly) or frequent (i.e., daily or weekly) smokers.[25,34,35] We assessed use frequency as the number of days in the past 30 days that participants smoked waterpipe tobacco.[9] We administered the 6-item Waterpipe Tobacco Dependence Scale[8] and summed the items to create a score (range = 0–25) with higher values indicating greater dependence (Cronbach's $\alpha = .77$).[8]

At the follow-ups, we used a series of items to assess waterpipe tobacco smoking frequency and cessation.[9] The first item assessed whether participants smoked waterpipe tobacco "even 1 or 2 puffs" since the last assessment. Among those responding no, the next item asked whether they completely stopped smoking waterpipe tobacco (yes or no). This captured cessation at each follow-up as point-prevalence abstinence.[33] Among those who had not quit, we assessed waterpipe tobacco smoking frequency at the follow-ups as described previously. For those who quit, we coded waterpipe tobacco smoking as zero at follow-ups. We analyzed as outcomes whether participants reported that they quit smoking waterpipe tobacco completely (yes or no) and the number of days in 30 days participants smoked waterpipe tobacco at each time point.

We measured motivation to quit smoking waterpipe tobacco at baseline and at the follow-ups among those who did not report quitting using a single item with a 1 (not at all) to 7 (very) scale.[35,44]

Statistical Analysis

We used descriptive statistics to characterize the sample overall and by arm. For risk appraisals and motivation to quit, we tested mean differences by trial arm at each time point using general linear models. Levene's test confirmed homogeneity of variance assumptions for each model (i.e., all $P > .05$). We interpreted the F statistic for trial arm and pairwise differences in least squares means using Tukey's adjustment for multiple comparisons.

For frequency of use, we used the Wilcoxon rank sum test for differences by trial arm. We interpreted the Kruskal–Wallis χ^2 statistic for trial arm and the Wilcoxon z test for pairwise comparisons between arms.

We used logistic regression to test if cessation differed by arm at each time point. We interpreted the χ^2 statistic for trial arm and the odds ratios (ORs) and 95% confidence intervals (CIs) for differences in cessation between arms. We ran 2 models for this outcome. The first model used data from those completing follow-ups only. The second model assumed that all those lost to follow-up had not quit smoking waterpipe tobacco.

For all outcomes, our primary comparison was the 6-month time point; earlier time points were prespecified as secondary. Sensitivity analyses controlling for baseline covariates that were not balanced by randomization (gender, race, cigarette smoking) did not differ for any outcomes, so we report unadjusted results.

Sample Size

We conducted a priori power calculations to determine the sample size needed to test for differences in the primary outcomes at 6 months between the trial arms assuming 2-tailed α of .05, 80% power, and 80% retention at 6 months. To detect mean differences as small as Cohen's d of 0.37 between trial arms in risk appraisals, motivation to quit, and use frequency and differences in cessation as small as 19% between trial arms, we needed to enroll 330 participants at baseline.

RESULTS

We screened 576 individuals for eligibility (Figure 1); 167 were ineligible (29%), 6 declined to participate (1%), 17 (3%) were withdrawn because they were later determined to be ineligible (e.g., provided inconsistent age), and we were unable to contact 37 (6%) after screening. In total, 349 participants enrolled and were randomized (Figure 1).

Table 1 displays baseline characteristics overall and by arm. Participants averaged 24.0 (SD = 3.4) years of age, 54% were female, 58% were non-White race, and 11.5% were Hispanic ethnicity. Nearly two thirds (65%) were frequent waterpipe smokers, and participants smoked waterpipe on average 11.5 (SD = 9.1) of the past 30 days. Overall, 29% were current cigarette smokers, and 68% reported other tobacco use. There were more cigarette smokers in the control arm, participants in the control arm were more likely to be female, and participants in the untailored arm were more likely to be White race.

Retention was 93% at 6 weeks (n = 324), 93% at 3 months (n = 325), and 91% at 6 months (n = 319). Attrition at the 3-month and 6-month follow-ups was higher in the tailored intervention arm (11% and 13%) than the control (3% and 5%) and untailored intervention (7% and 8%) arms.

There were no significant differences in risk appraisals between trial arms at 3 months or 6 months (Table 2). At 6 weeks, the effect of trial arm was significant ($F_{2324} = 3.1$; $P = .045$). Risk appraisals were significantly greater in the tailored arm (mean = 4.2; 95%

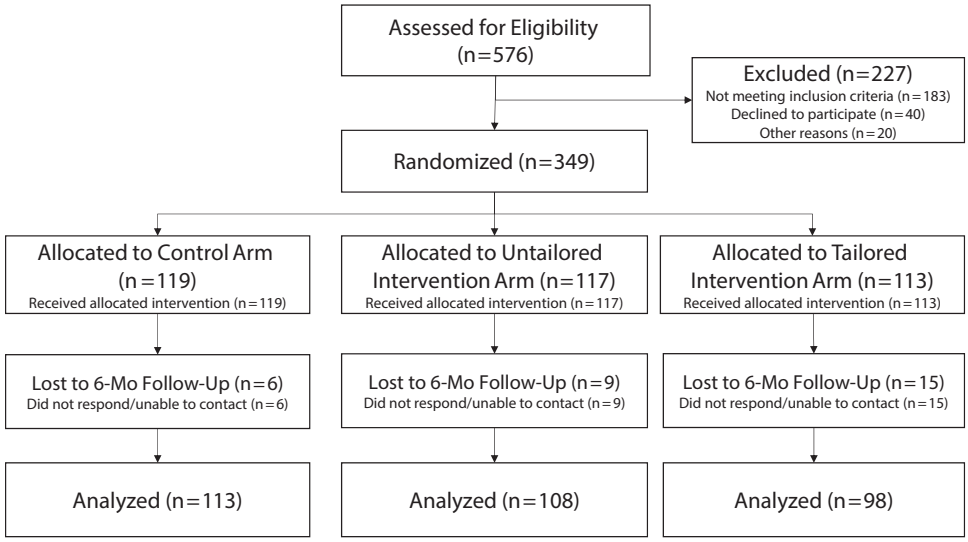

FIGURE 1— Flow Diagram for Randomized Trial of a Mobile Messaging Intervention for Waterpipe Tobacco Cessation in Young Adults: United States, 2018–2020

CI = 3.9, 4.4) than the control arm (mean = 3.8; 95% CI = 3.5, 4.0; $P = .039$). Results from analyses of individual items are shown in Table B.

At 6 months, waterpipe tobacco smoking frequency (Table 2) was significantly lower in the tailored arm (mean = 3.5 days; 95% CI = 2.0, 5.0) than the control arm (mean = 4.3 days; 95% CI = 3.0, 5.6; Kruskal–Wallis χ^2 for trial arm [2 *df*] = 9.2; $P = .010$; Wilcoxon $z = -3.1$; $P = .006$). At 6 weeks, smoking frequency was also significantly lower in the tailored arm than the control arm, and at 3 months it was significantly lower in the untailored and tailored arms than the control arm (Table 2).

Among those who did not quit smoking waterpipe tobacco, there were no significant differences in motivation to quit at 3 ($F_{2240} = 0.08$; $P = .923$) or 6 months by trial arm ($F_{2195} = 0.93$; $P = .398$; Table 2). Motivation to quit was significantly greater at 6 weeks in the tailored arm than the control arm (Table 2).

Table 3 shows outcomes for cessation. Using available data, at 6 months, cessation was significantly higher in the tailored arm (49%; OR = 2.4; 95% CI = 1.3, 4.2) than the control arm (29%; χ^2 for trial arm [2 *df*] = 8.8; $P = .012$). At 6 weeks and 3 months, cessation was significantly higher in the untailored and tailored arms than the control arm (Table 3). Assuming those lost to follow-up continued smoking waterpipe tobacco (Table 3), at 6 months, cessation was significantly higher in the tailored arm (43%; OR = 1.9; 95% CI = 1.1, 3.3) than the control arm (28%) but the overall effect of arm was no longer significant (χ^2 for trial arm [2 *df*] = 5.5; $P = .064$). At 6 weeks and 3 months, cessation was significantly higher in the untailored and tailored arms than the control arm (Table 3).

DISCUSSION

Our results demonstrate that a tailored mHealth messaging intervention increased cessation and decreased waterpipe tobacco smoking frequency among young adults. Although both the tailored and the untailored interventions affected outcomes at interim time points, for behavioral outcomes only, the tailored intervention effects were sustained to 6 months. These results build on previous research on waterpipe tobacco risk messages[34,35,45] by testing mHealth message delivery, demonstrating tailored messaging effects, and capturing behavioral outcomes.

There is limited research on waterpipe tobacco smoking cessation interventions for young adults[21–23] even though this is the age group in the United States when waterpipe tobacco smoking is most common.[9–12] This study is the first, to our knowledge, to demonstrate the efficacy of a tailored mHealth cessation intervention in young adult waterpipe tobacco smokers over a 6-month follow-up, filling a critical research gap. The mHealth intervention is highly scalable, aligning with major public health agencies' efforts to make mobile cessation interventions freely available. For example, the National Cancer Institute offers mHealth cessation programs for cigarette smoking and smokeless tobacco cessation, but not waterpipe tobacco

TABLE 1— Baseline Characteristics for Randomized Trial of a Mobile Messaging Intervention for Waterpipe Tobacco Cessation in Young Adults: United States, 2018–2020

	Overall (n = 349), Mean ±SD or % (No.)	Control (n = 119), Mean ±SD or % (No.)	Untailored Intervention (n = 117), Mean ±SD or % (No.)	Tailored Intervention (n = 113), Mean ±SD or % (No.)
Age	24.0 ±3.4	23.9 ±3.4	23.7 ±3.5	24.6 ±3.5
Gender				
Female	53.6 (187)	59.7 (71)	48.7 (57)	52.2 (59)
Male	46.4 (162)	40.3 (48)	51.3 (60)	47.8 (54)
Race				
White	42.1 (147)	42.9 (51)	36.8 (43)	46.9 (53)
Non-White	57.9 (202)	57.1 (68)	63.2 (74)	53.1 (60)
Hispanic ethnicity				
Yes	11.5 (40)	12.6 (15)	12.0 (14)	9.8 (11)
No	88.3 (308)	87.4 (104)	88.0 (103)	90.2 (101)
Education				
< college	16.0 (56)	13.4 (16)	20.5 (24)	14.2 (16)
Some college or higher	84.0 (293)	86.6 (103)	79.5 (93)	85.8 (97)
Employment				
Not full-time employed	58.1 (203)	56.3 (67)	63.2 (74)	46.0 (52)
Full-time employed	44.7 (156)	43.7 (52)	36.8 (43)	53.9 (61)
Annual household income, $				
≤ 50 000	65.3 (228)	62.2 (74)	63.2 (74)	70.8 (80)
> 50 000	34.4 (120)	37.8 (45)	35.9 (42)	29.2 (33)
Waterpipe smoking frequency				
Infrequent (i.e., monthly)	34.7 (121)	33.6 (40)	35.0 (41)	35.4 (40)
Frequent (i.e., weekly or daily)	65.3 (228)	66.4 (79)	65.0 (76)	64.6 (73)
Past-30-d waterpipe smoking, days	11.3 ±9.1	11.1 ±9.2	10.6 ±8.7	12.2 ±9.3
Waterpipe tobacco dependence	6.7 ±5.3	7.0 ±5.6	6.4 ±4.9	6.7 ±5.4
Motivation to quit waterpipe tobacco	2.7 ±1.6	2.9 ±1.6	2.5 ±1.6	2.6 ±1.6
Current cigarette smoker	29.2 (102)	37.8 (45)	24.8 (29)	24.8 (28)
Any other tobacco use, past 30 d	67.9 (237)	67.2 (80)	69.2 (81)	67.2 (80)
Days drinking alcohol, past 30 d	7.5 ±7.0	8.4 ±7.6	6.7 ±6.1	7.4 ±7.2

Note. For some variables (e.g., Hispanic ethnicity), numbers for categories do not sum to the total sample size because of sporadic missing data (1 or 2 cases in each instance).

cessation.[50] Our study provides the first evidence for a mHealth waterpipe tobacco smoking cessation intervention that can be implemented in this manner. Notably, waterpipe tobacco smoking is less prevalent than other forms of tobacco use (e.g., cigarette smoking) in the US population, but it is most common among young adults and it is associated with subsequent cigarette smoking initiation.[24] From a public health perspective, this intervention could be impactful if it is made available with other interventions designed to prevent and reduce tobacco use in young people overall.

A recent prospective analysis of US young adults' waterpipe tobacco smoking provides context for our findings.[13] Sharma et al. examined past-12-month waterpipe tobacco smoking over 3 years of PATH Study data, finding that 42% of young adults who smoked waterpipe tobacco at wave 1 continued smoking over the 3-year period, 47% discontinued by wave 3, and 11% discontinued at wave 2 and resumed smoking at wave 3.[13] This analysis examined past-12-month use, and it is unclear if "discontinuing" reflects cessation or

TABLE 2— Risk Appraisals, Past-30-Day Waterpipe Tobacco Smoking Frequency, and Motivation to Quit by Trial Arm: United States, 2018–2020

	Baseline (n = 349), Mean (95% CI)	6 Weeks (n = 324), Mean (95% CI)	3 Months (n = 325), Mean (95% CI)	6 Months (n = 319), Mean (95% CI)
Risk appraisals				
Control (A)	3.7 (3.5, 3.8)	3.8[C] (3.5, 4.0)	4.0 (3.7, 4.2)	4.0 (3.8, 4.3)
Untailored (B)	3.4 (3.2, 3.6)	3.9 (3.6, 4.1)	3.9 (3.7, 4.2)	4.0 (3.8, 4.3)
Tailored (C)	3.5 (3.3, 3.7)	4.2[A] (3.9, 4.4)	4.0 (3.8, 4.3)	4.3 (4.0, 4.5)
Waterpipe tobacco smoking frequency				
Control (A)	11.1 (9.4, 12.8)	7.8[C] (6.2, 9.5)	6.1[B,C] (4.6, 7.5)	4.3[C] (3.0, 5.6)
Untailored (B)	10.6 (9.0, 12.2)	5.4 (4.0, 6.8)	4.6[A] (3.2, 5.9)	4.0 (2.6, 5.2)
Tailored (C)	12.2 (10.4, 13.9)	5.4[A] (4.0, 6.8)	4.3[A] (3.0, 5.7)	3.5[A] (2.0, 5.0)
Motivation to quit				
Control (A)	2.9 (2.6, 3.2)	3.3[C] (3.0, 3.6)	3.8 (3.4, 4.2)	4.0 (3.5, 4.4)
Untailored (B)	2.5 (2.2, 2.8)	3.8 (3.4, 4.2)	3.9 (3.4, 4.3)	4.0 (3.5, 4.4)
Tailored (C)	2.6 (2.3, 2.9)	4.1[A] (3.7, 4.5)	3.9 (3.4, 4.4)	3.5 (3.0, 4.1)

Note. CI = confidence interval. For each time point, means for each outcome with different superscript letters differed significantly from the trial arm indicated (A = control; B = untailored; C = tailored) at $P < .05$. For risk appraisals and motivation to quit, comparisons of means are from general linear models with Tukey's adjustment for pairwise comparisons. For waterpipe tobacco smoking frequency, comparison of means is from Wilcoxon rank sum test and *z* test *P* values for pairwise comparisons. Waterpipe tobacco smoking frequency included all participants with those who quit at a given time point coded as 0. Motivation to quit only included those who had not quit smoking waterpipe tobacco at a given time point.

TABLE 3— Waterpipe Tobacco Cessation by Trial Arm at Follow-Up Time Points: United States, 2018–2020

	6 Weeks (n = 324)		3 Months (n = 325)		6 Months (n = 319)	
	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Available data						
Control	10	1 (Ref)	12	1 (Ref)	29	1 (Ref)
Untailored	24	2.8 (1.3, 5.8)	28	2.9 (1.4, 5.7)	38	1.5 (0.9, 2.6)
Tailored	22	2.5 (1.2, 5.2)	36	4.1 (2.1, 8.3)	49	2.4 (1.3, 4.2)
Assume lost to follow up continued smoking						
Control	10	1 (Ref)	12	1 (Ref)	28	1 (Ref)
Untailored	22	2.5 (1.2, 5.3)	27	2.7 (1.4, 5.4)	35	1.4 (0.8, 2.4)
Tailored	20	2.3 (1.1, 4.8)	33	3.7 (1.8, 7.2)	43	1.9 (1.1, 3.3)

Note. CI = confidence interval; OR = odds ratio. Table displays percentage reporting cessation and ORs (95% CIs) for cessation in the untailored and tailored intervention arms relative to the control arm at each time point. The first model with available data at each time point excludes those lost to follow-up. The second model at each time point assumes those lost to follow-up did not quit (i.e., continued smoking waterpipe tobacco).

intermittent use. However, the findings highlight the need to examine intervention outcomes over an extended follow-up. Some intervention effects we observed diminished over time, and assessing longer-term outcomes in the future will be important to determine if the effects are sustained and to assess maintenance of cessation and relapse.[51,52] This can guide future steps to optimize our intervention, such as testing adaptive models that provide additional support for those who do not quit or who relapse.[53]

Notably, many young adult waterpipe tobacco smokers are dual or poly tobacco users of other tobacco products.[13,54] In our sample, nearly one third

were cigarette smokers, and roughly two thirds used other tobacco. Although we observed intervention effects on waterpipe tobacco smoking, it is unclear if the intervention reduced tobacco use overall. Smoking cessation research has focused predominantly on exclusive tobacco product users (e.g., cigarette smokers) and existing interventions do not address dual or poly use.[55] Given the high prevalence of dual and poly use in young adults in general[55] and in young adult waterpipe smokers,[13,54] in future research it will be important to examine how interventions targeting waterpipe tobacco smoking affect other tobacco use outcomes in dual and poly users.

Limitations

This study has several important strengths, including a carefully developed mHealth intervention, rigorous trial design, and high retention. However, the findings should be interpreted in light of study limitations. We used remote (e.g., online, mobile) procedures for recruitment, data collection, and intervention delivery. These methods are increasingly used to improve efficiency of smoking cessation trials[56]; however, they are subject to limitations (e.g., potential reporting biases) that should be considered when interpreting the findings. We measured cessation by self-report. Although biochemically verified cessation is a gold standard in clinical trials,[57] established biomarkers (e.g., exhaled carbon monoxide, cotinine) cannot verify waterpipe tobacco smoking cessation in a population in which use of other combustible (e.g., cigarettes) and noncombustible (e.g., electronic cigarettes) products is common. Finally, assessing outcomes over a longer follow-up will provide more robust evidence on long-term intervention effects. We examined outcomes to 6 months as recommended for cessation trials,[33] but this will be important to understand if the effects are sustained.

Public Health Implications

This trial is the first, to our knowledge, to demonstrate the efficacy of a tailored mHealth messaging intervention for waterpipe tobacco smoking cessation in young adults. This is a scalable intervention model that aligns with ongoing efforts to make mHealth cessation interventions freely available to populations that need them. This study advances the science on waterpipe tobacco smoking cessation interventions, and the results suggest several important areas for further study. This includes examining long-term outcomes to assess if the effects are sustained and identify intervention optimization strategies for those who do not quit or who relapse, and examining intervention effects on other tobacco use in young adult dual and poly users. AJPH

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CONTRIBUTORS

D. Mays and I. M. Lipkus conceptualized the study and acquired funding. D. Mays, A. C. Johnson, L. Phan, C. Sanders, and I. M. Lipkus collected the data. D. Mays, A. C. Johnson, and A. Shoben analyzed the data. D. Mays wrote the first draft of the article. All authors revised the article and read and approved the final article.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

HUMAN PARTICIPANT PROTECTION

The study protocol was approved by the institutional review boards at Georgetown University and Duke University. The protocol for data analysis was also approved by the institutional review board at The Ohio State University.

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