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## Efficacy and Utilization of Smartphone Applications for Smoking Cessation among Low-income Adults: Secondary Analysis of the iCanQuit Randomized Trial

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### Abstract

**Introduction:** Evidence of digital interventions that are efficacious among low-income populations is scarce. In a secondary analysis, we determined the efficacy and utilization of an Acceptance and Commitment Therapy (ACT)-based smartphone application (iCanQuit) versus a U.S. Clinical Practice Guidelines (USCPG)-based smartphone application (QuitGuide) for smoking cessation in low-income adults enrolled in the iCanQuit randomized trial.

**Methods:** Participants were randomized to receive iCanQuit (n=437) or QuitGuide (n=460) for 12-months. Consistent with the main trial, the primary outcome was self-reported complete-case 30-day point prevalence abstinence (PPA) at 12-months. Secondary outcomes were 7-day PPA, missing-as-smoking and multiple imputation, prolonged abstinence, and cessation of all tobacco products at 12-months. Outcome data retention, utilization, and change in ACT-based processes were compared across arms.

**Results:** Participants were recruited from 48 U.S. states. Retention rate was 88% at 12-months and did not differ by arm. At 12-months, iCanQuit was 1.46 times more efficacious than QuitGuide for smoking cessation (27% vs. 20%; OR=1.46 95% CI: 1.04, 2.06). Findings were similar for missing-as-smoking imputation (23% vs. 18%; OR=1.41 95% CI: 1.01, 1.97) and multiple imputation at 12-months (27% vs. 20%; OR=1.51 95% CI: 1.07, 2.14). Treatment utilization was significantly higher among iCanQuit than QuitGuide participants. Increased acceptance of cues to smoke mediated the effect of treatment on cessation.

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**Conclusions:** The iCanQuit smartphone application was more efficacious and engaging for smoking cessation among low-income adults than a USCPG-based smartphone application. A nationwide dissemination trial of iCanQuit is warranted to determine whether iCanQuit may alleviate cessation-related disparities among low-income adults.

**Trial registration:** [ClinicalTrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT02724462) Identifier: [NCT02724462](https://clinicaltrials.gov/ct2/show/study/NCT02724462)

## Keywords

Acceptance & Commitment Therapy; low-income; iCanQuit; QuitGuide; smartphone applications; smoking cessation

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## 1. Introduction

In the United States (U.S.), cigarette smoking prevalence and the associated burden of disease are disproportionately greater among socioeconomically disadvantaged individuals.<sup>1,2</sup> This includes individuals with low incomes who are living close to or below the poverty threshold. Although cigarette smoking has declined to 14.0% in the general adult population, the smoking prevalence among individuals with annual incomes <\$35,000 is 21.4%.<sup>2</sup> Low-income individuals who smoke are also more likely to have lower levels of education, to report minority race or ethnicity, to be unemployed, and to reside in remote areas, with each additional disadvantage contributing to the smoking-related disparity.<sup>3,4</sup>

A major reason for this disparity in smoking rates is that low-income individuals have limited access to evidence-based smoking cessation treatments.<sup>5</sup> Less than a third of low-income adults who want to quit smoking have access to smoking cessation counseling or medication. Reasons for this limited access include lack of health insurance, living in remote areas, lack of knowledge about existing treatments, or discrimination due to smoking stigma.<sup>6-8</sup>

One potential way to address accessibility barriers is to offer freely available and remotely delivered smoking cessation treatments. Telephone-delivered interventions, although effective,<sup>9-11</sup> are limited by low levels of population reach. For example, state quitlines reach only 1–2% of smokers annually, thereby leaving substantial room for improvement.<sup>12-15</sup> For several reasons, digital interventions have the potential to provide an alternative to telephone-delivered approaches, with potential for greater reach and acceptability among low-income populations. First, digital interventions could reach those who have difficulty navigating the medical system, those who are uninsured, and those who experience discrimination due to smoking stigma. Second, the high portability of digital interventions, especially mobile interventions that are available at any time, helps remove barriers related to time and place, and therefore provides users with access to treatments that would not otherwise be feasible. Further, 85% of U.S. adults overall and 76% of adults earning less than \$30,000 annually reported that they owned a smartphone in 2021.<sup>16</sup> Therefore, smartphone interventions offer a means of increasing treatment access in this population. The potential of smartphones to reach and engage large populations of smokers has been demonstrated in previous efficacy trials of smartphone applications for smoking

cessation.<sup>17–19</sup> Although promising, little is known about the efficacy and utilization of smartphone applications for smoking cessation in low-income populations.

Low-income populations also face unique challenges to quitting smoking. Cigarette smoking may be used as a way to cope with highly stressful situations, such as unemployment, living in unsafe neighborhoods, financial strain, racial discrimination, and food insecurity.<sup>20–24</sup> These factors could reduce motivation to quit and further contribute to poor cessation outcomes.<sup>24–28</sup> Therefore, additional efforts to identify efficacious treatments that provide low-income populations with skills to cope with highly stressful environments that cue smoking are needed.

Acceptance and commitment therapy (ACT) is an evidence-based behavioral approach that has shown promise in smoking cessation interventions as evidenced by fifteen randomized clinical trials published that compared ACT to US Clinical Practice Guidelines interventions for smoking cessation,<sup>29</sup> and thus could address the need for more efficacious interventions for low-income individuals who smoke.<sup>30–32</sup> Through its focus on skills to accept sensations, emotions and thoughts, ACT-based interventions could provide low-income individuals with unique skills to effectively cope with stressors that are known to be associated with poor smoking cessation outcomes. ACT teaches acceptance of internal cues to smoke rather than avoidance, which may be impractical in low-income neighborhoods with high density of tobacco retailers and tobacco advertisements.<sup>33</sup>

Smartphone applications offer a potentially high impact means of making ACT-based interventions for smoking cessation accessible to low-income populations. The efficacy of an ACT-based smartphone application (iCanQuit) was previously tested against a U.S. Clinical Practice Guidelines (USCPG)-based smartphone application (QuitGuide) in a large two-arm randomized trial among 2,415 daily adult smokers nationwide.<sup>34</sup> At 12-months, iCanQuit was 1.5 times more efficacious than QuitGuide for smoking cessation. Moreover, results from this study also showed that the effect of the intervention on smoking cessation was mediated through increase in acceptance of cues to smoke.<sup>35</sup> However, the efficacy of iCanQuit for smoking cessation, specifically among low-income adults, has not been evaluated.

Therefore, this study determined the efficacy and utilization of iCanQuit relative to QuitGuide for smoking cessation among low-income adults enrolled in the iCanQuit randomized trial. We hypothesized that, compared with the QuitGuide arm, low-income adults in the iCanQuit arm would have higher quit rates and treatment utilization. We further hypothesized that ACT-based processes, especially acceptance of cues to smoke would mediate the effect of treatment on smoking cessation.

## 2. Methods

### 2.1. Design

Data are from the two-arm randomized iCanQuit parent trial that enrolled adult (18 years) daily smokers with smartphone access who wanted to quit smoking.<sup>17</sup> Exclusion criteria included being unable to read English, receiving smoking cessation treatment, having used

QuitGuide in the past, or having a household member already enrolled in the study. Details of the iCanQuit trial were previously published.<sup>17</sup> Briefly, 2,415 adults were randomized 1:1 to receive iCanQuit or QuitGuide for 12-months. All participants were screened for eligibility via online surveys and provided informed consent online. Study procedures were approved by the Fred Hutchinson Cancer Research Center Institutional Review Board. All participants were compensated up to \$105 for completing study outcome data collection. No compensation was provided for the utilization of the treatment applications.

## 2.2. Population, recruitment, and enrollment

For this analysis, iCanQuit trial participants who reported gross household annual incomes of <\$20,000 (863/2415, 35.7%) were selected, which was the lowest of three possible income response options on the baseline study survey (Less than \$20,000, \$20,000 - \$54,999, and \$55,000 or more). This level of income is significantly below the median income for family households in the U.S. (\$41,232/year in 2019);<sup>36</sup> and is also below the \$35,000/year threshold which is used by the Centers for Disease Control and Prevention to reflect the lowest level of income when comparing cigarette smoking prevalence across income levels.<sup>37</sup> Low-income trial participants were recruited via Facebook ads (735/863, 85%), a survey sampling company (91/863, 11%), search engine (18/863, 2%), and word of mouth (20/863, 2%). Although, recruitment was not tailored to low-income populations, the design of the study was intentional in including specific parameters in the Facebook ads that were tailored to low-income interests and employers that tend to pay lower wages, like retail, food service, construction, and manufacturing (e.g., Walmart, McDonald's, GMC). Participants were enrolled between May 2017 and September 2018. Participants were given access to their assigned application with a unique access code, from the moment of randomization. E-mails with a unique link to an online survey were sent to participants at 3, 6 and 12-month follow-ups. Follow-up data collection was between August 2017 and December 2019 via the online survey platform.

## 2.3. Interventions

**2.3.1. iCanQuit**—The iCanQuit smartphone application (version 1.2.1) teaches ACT skills for coping with smoking urges, staying motivated, and preventing relapse.<sup>17</sup> The content is delivered in eight levels, including on-demand help with coping with smoking urges, daily tracking of cigarettes smoked, and urges experienced without smoking. The program is self-paced, and content is unlocked in a sequential manner. If a participant lapses, the program encourages (but does not require) them to set a new quit date and return to the first five levels for preparation. iCanQuit targeted two core processes of ACT: acceptance and values. The acceptance component of the application teaches skills to accept sensations, emotions, and thoughts that trigger smoking via distancing from thoughts about smoking, mindfulness, and perspective taking. This teaching of acceptance is conceptually distinct from USCPG-based standard approaches that teach avoidance of internal cues to smoke. The values component of the application teaches skills for determining the core life domains that motivate quitting smoking (e.g., family, health, spirituality) and taking repeated small actions within these domains (e.g., playing with grandchildren) to develop a smoke-free life. This focus on motivation by appealing to values is conceptually distinct from USCPG-based standard approaches that motivate by focusing on reasons for change.

### 2.3.2. QuitGuide

The USCPG-based QuitGuide smartphone application (version 1.2.2) focuses on increasing motivation to quit by using reason and logic and providing information on the health consequences of smoking. The application helps users develop a quit plan, identify smoking behaviors, triggers, and reasons for being smoke-free, and to identify sources of social support for quitting. It teaches skills for avoiding situations that lead to cravings to smoke, staying smoke-free, and coping with slips. More details on the similarities and differences of the two smartphone applications have been previously published.<sup>17</sup> No incentives, coaching, or other interventions were provided in either arm. Similar to real-world use of smartphone applications, participants could reach out to our staff for technical support though this occurred very rarely. Both interventions provided information on U.S. Food and Drug Administration-approved medications for quitting smoking but did not provide any pharmacotherapy.

## 2.4. Measures

**2.4.1. Baseline measures**—Data collected at baseline included socio-demographic characteristics and home zip codes.<sup>38–40</sup> Alcohol consumption was assessed via the Quick Drinking Screen.<sup>41</sup> Smoking behavior variables included the Fagerström Test for Nicotine Dependence (FTND),<sup>42</sup> number of cigarettes smoked per day, years of smoking, use of e-cigarettes in past month, quit attempts during the past 12-months, confidence in quitting smoking (0–100, where 0 indicates not confident at all and 100 indicates extremely confident), and number of close relationships with other smokers.

**2.4.2. Smoking cessation**—Smoking cessation outcomes were measured at the 3, 6 and 12-month follow-ups. The primary smoking cessation outcome was self-reported complete-case 30-day point-prevalence abstinence (PPA) at 12-months, consistent with the iCanQuit parent trial.<sup>17</sup> Secondary smoking cessation outcomes were 7-day PPA, missing-as-smoking imputation, multiple imputation sensitivity analysis, prolonged abstinence defined as no smoking at all in the 9-month period of 3 to 12-months post-randomization, and cessation of all nicotine and tobacco products, including any kind of e-cigarettes or vaping, chewing tobacco, snus, hookahs, cigars, cigarillos, tobacco pipes, and kreteks at 12-months.

**2.4.3. ACT-based processes**—Acceptance of internal cues to smoke was measured via the Avoidance and Inflexibility Scale (AIS-27 adapted from Gifford et al.)<sup>43</sup> which includes three subscales that assess one’s willingness to experience physical sensations, emotions, and thoughts that cue smoking. The 27 items are rated on a 5-point scale from (1) “Not at all” to (5) “Very willing” and averaged, with higher scores indicating greater acceptance. Valued living was measured via the 10-item Valuing Questionnaire<sup>44</sup> designed to assess the extent of personal values (e.g., family, health, spirituality) enactment. Items are intended to capture the quality of life of valued action in everyday language and without reference to specific life domains. Each item is rated on a 7-point scale ranging from (0) “Not at all true” to (6) “Completely true”. Scores were averaged and two distinct factors were derived, progress and obstruction with higher scores indicating either greater progress or greater obstruction toward valued living, respectively. Cronbach’s alpha (95% CI) for each

of the three scales showed good internal consistency: (1) mean acceptance, 0.72 (0.69, 0.77); (2) valued living, progress subscale, 0.88 (0.87, 0.89); and (3) valued living, obstruction subscale 0.87 (0.86, 0.89).

**2.4.4. Treatment utilization and satisfaction**—Treatment utilization was objectively measured by Google Analytics (number of times the application was opened, the time spent per session, and the number of unique days of use). An 11-item measure of satisfaction with the intervention, adapted from previous research,<sup>30,32</sup> was completed at the 3-month follow-up.

## 2.5. Statistical analysis

Baseline characteristics for low-income participants are described overall and by treatment arm. Zip codes were tied to geographic location using the R library „zipcode“<sup>45</sup> and were categorized as urban or rural using Rural-Urban Commuting Area (RUCA) codes.<sup>46</sup> RUCA codes of 1–3 were considered urban, while RUCA codes of 4–10 were considered rural.<sup>47–50</sup> Logistic regression models were used to compare binary smoking cessation outcomes and outcome data retention rates between arms at all timepoints, as well as binary satisfaction outcomes. Outcome data retention rates (%) were calculated as the number of participants who completed study data collection at each follow-up time point (3, 6 and 12-months) out of the total number of participants included in the imputed missing-as-smoking analysis (see Figure 1). As a sensitivity analysis, multiple imputation was used to estimate missing 30-day PPA at 12-months. Effect sizes and standard errors from ten imputed datasets were pooled using Rubin’s rules<sup>51</sup> to generate a single OR and 95% confidence interval. Generalized linear models were used to compare changes from baseline to 3-months in ACT-based processes and utilization data. Full utilization data up to 12-months was not available due to a technical error by Google Analytics. For this reason, we reported utilization for participants with full 6-months of data. Right-skewed count outcomes were compared using negative binomial models. All models were adjusted for factors used in stratified randomization<sup>52</sup> including daily smoking frequency (20 vs.21 cigarettes/day), minority race/ethnicity, education level (high school vs. some college), and positive screening for depression (CESD-20 score 15 vs.16).<sup>38</sup> Hayes’ PROCESS macro for SAS was used to test the potential mediation of the effect of treatment on cessation at 12-months by changes in acceptance and valued living at 3-months.<sup>53</sup> Indirect effects were estimated with 5,000 bootstrapped samples and were considered statistically significant when bias-corrected 95% confidence intervals did not include zero. All statistical tests were 2-sided, with  $\alpha=.05$ . Regression analyses were completed using R, version 4.0.3, library „MASS“ for negative binomial regression, and library „mice“ for multiple imputation.<sup>54–56</sup>

## 3. Results

### 3.1. Enrollment and outcome data retention

A total of 12,881 individuals were screened, 6,559 were eligible and 3,470 consented to participate in the iCanQuit parent trial (Figure 1). The main reason for ineligibility was not providing consent (22%). For this analysis, all 897 randomized participants with annual incomes of <\$20,000 were included. These participants were randomly assigned to receive

QuitGuide (n=437) or iCanQuit (n=460) application for 12-months. Of the 897 randomized, 34 (4%) were excluded because another household member was already enrolled in the study, or they enrolled twice. The retention rates were 87%, 90%, and 88% at the 3, 6, and 12-month follow-ups, respectively, with no differential retention rate by arm at any follow-up time point (all  $p$ 's > .05).

### 3.2. Participant characteristics

Participants were an average 37 years old, 28% male, 39% from racial minority groups in the US (Black or African American, American Indian or Alaska Natives, Asian, Native Hawaiian or Pacific Islander, or more than one race), and 10% Hispanic or Latino (Table 1). More than half (55%) had a high school diploma or lower education attainment, 24% were disabled and 19% were unemployed. The majority were long-time smokers (79% smoked 10 years) and had high nicotine dependence (65% FTND score 6). Figure 2 shows the geographic location and rural (24%) vs. urban (74%) residence of low-income participants included in this analysis that were recruited from 48 U.S. states.

### 3.3. Smoking cessation

The self-reported complete-case 30-day PPA was 27% (105/387) for iCanQuit vs. 20% (74/370) for QuitGuide at 12-months (OR=1.46 95% CI: 1.04, 2.06), 25% vs. 14% at 6-months (OR=2.15 95% CI: 1.48, 3.12), and 17% vs. 11% at 3-months (OR=1.67 95% CI: 1.10, 2.56) (Table 2). The missing-as-smoking imputed 30-day PPA at 12-months was 23% for iCanQuit vs. 18% for QuitGuide (OR=1.41; 95% CI: 1.01, 1.97). Rates of prolonged abstinence at 12-months were 12% for iCanQuit vs. 8% for QuitGuide (OR=1.43; 95% CI: 0.83, 2.45). The 30-day PPA for cessation from all nicotine and tobacco products, including e-cigarettes and vaping, was 25% for iCanQuit vs. 16% for QuitGuide at 12-months (OR=1.71 95% CI: 1.19, 2.46). The 7-day PPA was 33% for iCanQuit vs. 27% for QuitGuide at 12-months (OR=1.29 95% CI: 0.94, 1.77), 35% vs. 24% at 6-months (OR=1.69 95% CI: 1.23, 2.32), and 29% vs. 17% at 3-months (OR=1.96 95% CI: 1.38, 2.78). Multiple imputation 30-day PPA at 12-months resulted in quit rates of 27% for iCanQuit vs. 20% for QuitGuide (OR=1.51 95% CI: 1.07, 2.14).

### 3.4. Change of ACT-based process mediators

Indirect effects of the treatment on cessation through ACT-based processes are shown in Table 3. Increases in acceptance of sensations ( $p < 0.001$ ), emotions ( $p = 0.001$ ), and thoughts ( $p = 0.001$ ) that cue smoking between baseline and 3-months were significantly greater among iCanQuit than QuitGuide participants. Change in progress and obstruction of valued living did not differ between arms ( $p > 0.05$ ). Baseline to 3-month increases in mean acceptance (indirect effect: 0.27; 95% CI: 0.13, 0.45) mediated the relationship between treatment and cessation at 12-months. In contrast, baseline to 3-month changes in the progress and obstruction measures of valued living did not mediate this relationship. Further analysis showed that baseline to 3-months increases in acceptance of emotions that cue smoking, but not in acceptance of sensations or thoughts that cue smoking mediated the relationship between treatment and cessation at 12-months (Supplementary Table 1).

### 3.5. Treatment utilization and satisfaction

The effects of treatment group assignment on treatment utilization and satisfaction are presented in Table 4. Compared with QuitGuide participants, iCanQuit participants opened the application on nearly three times more occasions over a period of 6-months (25.2 vs. 8.8 times,  $p<0.001$ ), spent nearly two times longer using the application (4.6 vs. 2.5 minutes per session,  $p<0.001$ ), and used the application on nearly three times more days (16.8 vs. 5.9 days,  $p<0.001$ ). Overall treatment satisfaction did not differ between arms (86% iCanQuit vs. 82% QuitGuide,  $p=0.121$ ). Compared with QuitGuide participants, iCanQuit participants found the application more useful for quitting (81% vs. 74%,  $p=0.031$ ), they were more likely to recommend the application (84% vs. 77%,  $p=0.016$ ), and they were more likely to report that they felt like the application was “made for them” (81% vs. 72%,  $p=0.005$ ).

## 4. Discussion

Using data from a full-scale randomized trial with long-term follow-up, this study demonstrated that, among low-income adults, the iCanQuit smartphone application was more efficacious for smoking cessation than the USCPG-based QuitGuide smartphone application. The self-reported complete-case 30-day PPA for cessation at 12-months was 27% for iCanQuit vs. 20% for QuitGuide participants. Findings were similar for missing-as-smoking imputation and for the multiple imputation analysis. Results in this study were also comparable with those found in the main iCanQuit trial (28% vs. 21%; OR=1.49 95% CI: 1.22, 1.83).<sup>17</sup> Outcome data retention rate was 88% at 12-months and did not differ by arm.

These results are a major advance over the existing body of literature on smartphone applications, which has consisted of single-arm designs and feasibility pilot trials.<sup>57–59</sup> For example, Hébert et al.<sup>59</sup> conducted a randomized pilot trial on the use of an automated smartphone-based application (Smart-T2) compared with QuitGuide and in-person usual care among 81 low-income adults who smoked. The 7-day PPA rates at the 3-month follow-up were 22% for Smart-T2, 15% for QuitGuide and 15% for usual care. Although user engagement was high, higher quit rates in the Smart-T2 arm did not reach statistical significance. Compared to the broader literature of digital interventions for smoking cessation among socioeconomically disadvantaged populations (e.g., low education, unemployed or manual occupation) with 6-month or longer follow-ups, studies have tested text messages,<sup>60,61</sup> interactive websites,<sup>62</sup> or a combination thereof.<sup>63</sup> Quit rates have ranged between 10.7 to 19.9% for text messages alone and between 7.3 to 9.0% for interactive websites or video-based interventions plus text messages, and thus the higher quit rates for the iCanQuit application show great promise.

To understand why iCanQuit was efficacious, acceptance and valued living measures were explored as potential mediators. These analyses showed that ACT-based processes help low-income adults quit smoking via increases in acceptance of internal cues to smoke, but not via valued living measures. Stress and social disadvantage are strong triggers to smoke and consistent triggers of relapse among low-income individuals who may use smoking as a way to cope with highly stressful situations.<sup>28,64</sup> Our results suggest that providing low-income adults with skills to increase their willingness to experience cravings to smoke without trying to control them in potentially stressful situations could be a key process



underlying abstinence. Future studies should further explore these key mediators in this group.

This study showed much higher utilization of iCanQuit than the QuitGuide application among low-income adults, suggesting that smartphone applications for smoking cessation are engaging in this population. While the specific reasons why iCanQuit was more engaging are beyond the scope of this paper, the evaluation of predictors of utilization of smartphone interventions for smoking cessation in this population is a worthwhile topic for future research. And although overall satisfaction was high for both treatment arms, iCanQuit participants were significantly more likely to report that they felt the application was “made for them”.

There are several strengths of this study. First, the study was successful in recruiting a racially/ethnically and geographically diverse sample (39% minority race/ethnicity, 24% rural residence) from 48 U.S. states, thereby demonstrating potential for broad reach. Second, outcome data retention rates were high, with 88% of study participants retained at 12-months among one of the largest populations of low-income adults enrolled in a digital intervention for smoking cessation. Participant recruitment methods to increase diversity and reduce attrition are described elsewhere.<sup>65</sup> Third, participants were not compensated for the use of the smartphone applications. Lastly, iCanQuit’s high cessation rates were achieved without provision of any pharmacotherapy or coaching,<sup>9</sup> which makes the intervention lower cost and logistically easier to disseminate. Rates of outside pharmacotherapy use, or coaching did not differ by treatment arm (results not shown).

The study also has limitations. First, the results are from a secondary analysis of a two-arm randomized parent trial and as such, the results are exploratory, rather than definitive. Second, the trial and interventions were not tailored to low-income individuals. However, a review of smoking cessation interventions among socioeconomically disadvantaged individuals concluded that there were no added benefits of tailoring approaches in this group when compared with non-tailored approaches.<sup>66</sup> Third, smoking status was not biochemically-verified. The self-reported outcome was prespecified based on methodological problems with remote biochemical verification in remote population-based studies: (1) high attrition, (2) difficulty with identifying the person providing the sample, and (3) high-cost relative to the prospect of falsifying abstinence in low-touch interventions.<sup>67,68</sup> Previous studies have demonstrated strong agreement between self-reported and biochemically verified smoking status,<sup>69,70</sup> while others showed evidence of significant discordance.<sup>71,72</sup> Therefore, the external validity of the self-reported smoking status in this trial is not known. However, given the double blinding of the trial, we see no compelling reason the false reporting rate would be higher in one intervention arm versus the other, and thus there is no strong rationale for a bias in the odds ratios. Lastly, full utilization data up to 12-months was not available due to a technical error by Google Analytics. Because participants were unaware of the error, the missing data after 6 months is unlikely to change the validity of the results.<sup>73</sup>

#### 4.1. Conclusions

In a racially diverse sample with high outcome data retention and treatment utilization, this study showed that, among low-income adults, the iCanQuit smartphone application was more efficacious for smoking cessation than a USCPG-based smartphone application. A nationwide dissemination trial of iCanQuit is warranted to determine whether the iCanQuit application may alleviate cessation-related disparities among low-income adults.

#### Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Author Disclosures

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#### Abbreviations:

<b>ACT</b>	Acceptance and Commitment Therapy
<b>CI</b>	95% confidence interval
<b>FTND</b>	Fagerström Test for Nicotine Dependence
<b>GED</b>	General Education Development
<b>LGBT</b>	lesbian, gay, bisexual, or transgender
<b>OR</b>	odds ratio
<b>PPA</b>	point-prevalence abstinence
<b>PTSD</b>	posttraumatic stress disorder
<b>RCT</b>	randomized clinical trial
<b>RUCA</b>	Rural-Urban Commuting Area
<b>USCPG</b>	United States Clinical Practice Guidelines
<b>U.S.</b>	United States

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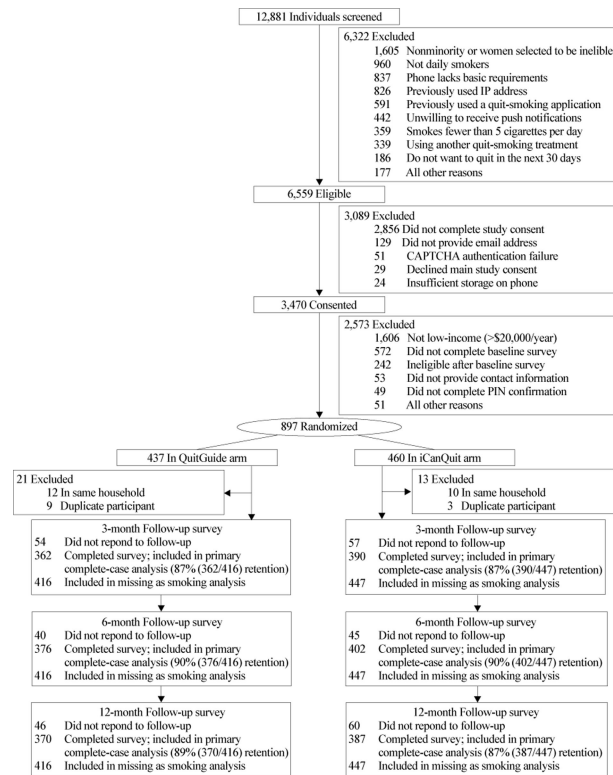
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### Highlights

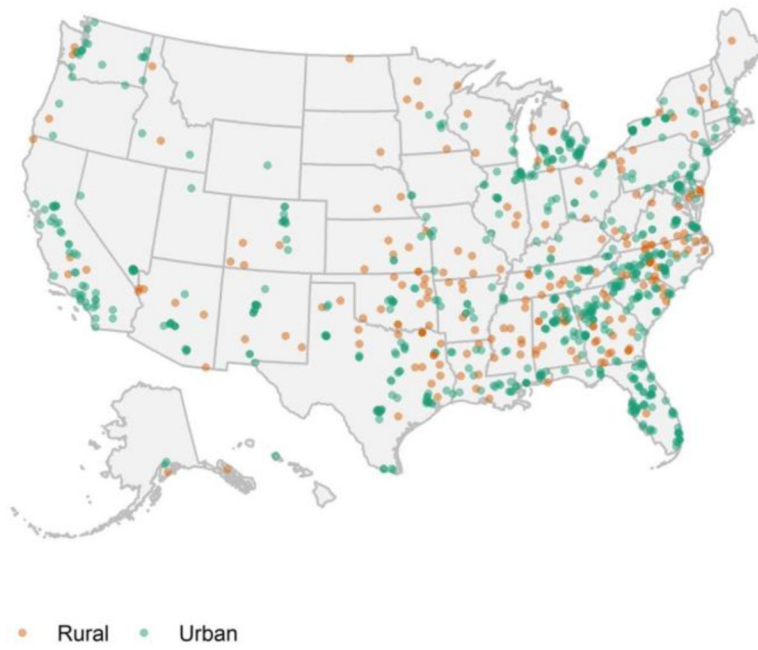
- Smartphone interventions can help reduce smoking disparities in low-income adults.
- iCanQuit was more efficacious than QuitGuide for cessation in low-income adults.
- iCanQuit application was more engaging than QuitGuide in low-income adults.
- Acceptance of cues to smoke mediated the effect of treatment on smoking cessation.



**Figure 1.**  
CONSORT Diagram

<sup>a</sup>To increase enrollment of racial/ethnic minorities and men, some nonminorities and women who were eligible for study enrollment were randomly selected to be excluded. Retention rates (%) were calculated as the number of participants who completed study data collection at each follow-up time point (3, 6 and 12-months) out of the total number of participants included in the imputed missing as smoking analysis. The missing as smoking analysis assumes that data are missing not at random, and that those who were lost to follow-up failed to quit.





**Figure 2.**  
Geographic locations of low-income trial participants

**Table 1.**

Baseline socio-demographic characteristics of low-income trial participants

Characteristic	n	No. (%) or Mean (SD)		
		Total (N = 863)	QuitGuide (n = 416)	iCanQuit (n = 447)
Age, mean (SD)	863	36.9 (11.1)	36.7 (11.2)	37.2 (11.1)
Male	863	244 (28%)	128 (31%)	116 (26%)
Race, <i>n</i> =846				
White	846	519 (61%)	246 (60%)	273 (62%)
Black or African American	846	232 (27%)	117 (29%)	115 (26%)
Multiracial	846	67 (8%)	32 (8%)	35 (8%)
American Indian or Alaska Native	846	25 (3%)	10 (2%)	15 (3%)
Native Hawaiian or Pacific Islander	846	2 (<1%)	1 (<1%)	1 (<1%)
Asian	846	1 (<1%)	1 (<1%)	0 (0%)
Hispanic or Latino ethnicity	830	83 (10%)	45 (11%)	38 (9%)
Education				
Less than GED or high school education	863	125 (14%)	64 (15%)	61 (14%)
GED	863	127 (15%)	56 (13%)	71 (16%)
High school diploma	863	222 (26%)	110 (26%)	112 (25%)
Some college, no degree	863	279 (32%)	139 (33%)	140 (31%)
College degree or higher	863	110 (13%)	47 (11%)	63 (14%)
Employment status				
Employed	863	342 (40%)	164 (39%)	178 (40%)
Unemployed	863	166 (19%)	75 (18%)	91 (20%)
Disabled	863	204 (24%)	101 (24%)	103 (23%)
Out of labor force	863	151 (17%)	76 (18%)	75 (17%)
Rural residence	863	207 (24%)	103 (25%)	101 (23%)
Married	863	163 (19%)	87 (21%)	76 (17%)
LGBT	863	166 (19%)	78 (19%)	88 (20%)
Alcohol use				
Heavy drinker <sup>3</sup>	833	115 (14%)	52 (13%)	63 (15%)
No. of drinks/drinking day, mean (SD)	833	1.8 (4.0)	1.7 (4.0)	1.8 (4.1)
Smoking behavior				
FTND score, mean (SD)	863	6.1 (1.9)	6.2 (1.9)	6.1 (2.0)
High nicotine dependence (FTND score > 6)	863	560 (65%)	266 (64%)	294 (66%)
Smokes more than one-half pack/d	863	617 (71%)	308 (74%)	309 (69%)
Smokes more than 1 pack/d	863	168 (19%)	78 (19%)	90 (20%)
First cigarette within 5 min of waking	863	533 (62%)	266 (64%)	267 (60%)
Smoked for >10 years	863	679 (79%)	329 (79%)	350 (78%)
Used e-cigarettes at least once in past month	863	188 (22%)	92 (22%)	96 (21%)

Characteristic	No. (%) or Mean (SD)			
	n	Total (N = 863)	QuitGuide (n = 416)	iCanQuit (n = 447)
Quit attempts in past 12 months, mean (SD)	819	1.3 (2.7)	1.4 (3.0)	1.2 (2.4)
Confidence to quit smoking, mean (SD) <sup>b</sup>	863	65.8 (27.8)	66.7 (27.6)	65.0 (27.9)
Friend and partner smoking				
Close friends who smoke, mean (SD)	863	2.9 (1.8)	2.9 (1.8)	3.0 (1.7)
No. of housemates who smoke, mean (SD)	863	1.4 (0.8)	1.4 (0.9)	1.4 (0.8)
Living with partner who smokes	863	274 (32%)	129 (31%)	145 (32%)
ACT theory-based measures				
Acceptancê mean (SD)				
Physical sensations	851	3.0 (0.6)	3.0 (0.6)	3.0 (0.6)
Emotions	856	2.8 (0.4)	2.8 (0.5)	2.8 (0.4)
Thoughts	858	2.8 (0.4)	2.8 (0.4)	2.7 (0.4)
Acceptance mean score	849	2.9 (0.4)	2.9 (0.4)	2.9 (0.4)
Valued living <sup>d</sup> , mean (SD)				
Progress <sup>e</sup>	852	18.5 (8.1)	18.9 (8.1)	18.1 (8.1)
Obstruction <sup>f</sup>	851	13.1 (8.6)	13.0 (8.5)	13.3 (8.7)

Abbreviations: ACT, Acceptance and Commitment Therapy; FTND, Fagerström Test for Nicotine Dependence; GED, General Education Development; LGBT, lesbian, gay, bisexual, or transgender; PTSD, Posttraumatic Stress Disorder.

<sup>a</sup>Heavy drinking is defined as 4 or more drinks on a typical drinking day for women and 5 or more drinks on a typical drinking day for men within the past 30 days.

<sup>b</sup>Range, 0–100, where 0 indicates not at all confident and 100 indicates extremely confident.

<sup>c</sup>Avoidance and Inflexibility Scale. Range is 1 to 5. Higher scores indicate greater acceptance.

<sup>d</sup>Valuing Questionnaire.

<sup>e</sup>Range is 0 to 30. Higher scores indicate greater progression towards one's values.

<sup>f</sup>Range is 0 to 30. Higher scores indicate greater obstruction of one's values.

**Table 2.**  
Smoking cessation outcomes by follow-up time point<sup>b</sup>

Variable	No. (%) or Mean (SD)				OR (95% CI)	p value
	Overall (N = 863)	QuitGuide (n = 416)	iCanQuit (n = 447)			
12-months outcomes						
30-d PPA	179/757 (24%)	74/370 (20%)	105/387 (27%)		1.46 (1.04, 2.06)	0.030
30-d PPA, missing-as- smoking <sup>c</sup>	179/863 (21%)	74/416 (18%)	105/447 (23%)		1.41 (1.01, 1.97)	0.046
30-d PPA, multiple imputation <sup>d</sup>	2035/8630 (24%)	823/4160 (27%)	1212/4470 (20%)		1.51 (1.07, 2.14)	0.020
7-d PPA	226/757 (30%)	100/370 (27%)	126/387 (33%)		1.29 (0.94, 1.77)	0.116
Prolonged abstinence <sup>e</sup>	60/598 (10%)	25/296 (8%)	35/302 (12%)		1.43 (0.83, 2.45)	0.199
30-d PPA of all tobacco products <sup>f</sup>	157/758 (21%)	60/371 (16%)	97/387 (25%)		1.71 (1.19, 2.46)	0.004
6-months outcomes						
30-d PPA	153/778 (20%)	51/376 (14%)	102/402 (25%)	139/402 (35%)	2.15 (1.48, 3.12)	<0.001
7-d PPA	229/778 (29%)	90/376 (24%)	139/402 (35%)		1.69 (1.23, 2.32)	0.001
3-months outcomes						
30-d PPA	107/752 (14%)	40/362 (11%)	67/390 (17%)		1.67 (1.10, 2.56)	0.017
7-d PPA	176/752 (23%)	63/362 (17%)	113/390 (29%)		1.96 (1.38, 2.78)	<0.001

Abbreviations: OR, odds ratio; PPA, point prevalence abstinence

<sup>a</sup> All models include the following covariates: education (high school diploma or less), heavy smoking (>20 cigs/day), minority race or ethnicity and depression symptoms (CESD-2016).

<sup>b</sup> All outcomes are complete case (i.e., exclusion of participants lost to follow-up) was specified a priori as the primary outcome, except where noted.

<sup>c</sup> Intent-to-treat missing-as-smoking analysis was specified a priori as a secondary outcome.

<sup>d</sup> Multiple imputation sensitivity analysis was used to estimate missing 30-day PPA at 12-months. Effect sizes and standard errors from ten imputed datasets were pooled using Rubin's rules<sup>51</sup> to generate a single OR and 95% confidence interval.

<sup>e</sup> Defined as no smoking since 3-months post-randomization, using self-reported data of last cigarette.

<sup>f</sup> Including any kind of e-cigarettes or vaping, chewing tobacco, snus, hookahs, cigars, cigarillos, tobacco pipes, and kreteks.

**Table 3.**

Change in ACT-theory based processes from baseline to 3-months as mediators of the effect of treatment on the primary cessation outcome<sup>a,b</sup>

Mediator	n	Change from baseline to 3-months			Point estimate for difference (95% CI)	P value	Estimate of mediation effect (95% CI)
		Overall (N = 863)	QuitGuide (n = 416)	iCanQuit (n = 447)			
Acceptance to internal cues to smoke Mean Acceptance Score <sup>c</sup>	710	0.2 (0.6)	0.1 (0.5)	0.2 (0.6)	0.15 (0.08, 0.23)	<0.001	0.27 (0.13, 0.45)*
Valued living <sup>d</sup> Progress	726	-0.3 (8.3)	-0.5 (8.4)	-0.2 (8.2)	-0.1 (-1.2, 0.9)	0.828	0.00 (-0.03, 0.02)
Obstruction	725	-0.4 (8.7)	0.1 (8.3)	-0.9 (9.0)	-0.9 (-2.0, 0.2)	0.104	0.00 (-0.03, 0.02)

Abbreviations: ACT, Acceptance and Commitment Therapy; PPA, point prevalence abstinence

<sup>a</sup>All models include the following covariates: education (high school diploma or less), heavy smoking (>20 cigs/day), minority race or ethnicity and depression symptoms (CESD-2016).

<sup>b</sup>All changes in acceptance scores calculated as follow-up minus baseline. Negative score indicates measure was higher at baseline.

<sup>c</sup>Avoidance and Inflexibility Scale. Mean acceptance score includes the three subscales of acceptance, including acceptance of sensations, emotions, and thoughts that cue smoking. Range is -4 to 4. Positive scores indicate higher acceptance at follow-up.

<sup>d</sup>Valuing Questionnaire. Range is -30 to 30. Positive scores indicate higher subscale scores at follow-up.

\* p<0.05.

**Table 4.**Treatment utilization and satisfaction of the assigned smartphone application<sup>a</sup>

Variable	n	Mean (SD) or No. (%)			IRR, point estimate or Odds Ratio (95% CI)	p value
		Overall (N = 863)	QuitGuide (n = 416)	iCanQuit (n = 447)		
Utilization at 6 months <sup>b</sup>						
No. of times opened, mean (SD)	850	17.3 (42.7) <sup>c</sup>	8.8 (37.6) <sup>d</sup>	25.2 (45.5) <sup>e</sup>	IRR: 3.02 (2.50, 3.64)	<0.001
Time spent per session, mean (SD), min	761	3.6 (4.5)	2.5 (2.2)	4.6 (5.7)	Point estimate: 2.0 (1.4, 2.6)	<0.001
No. of unique days of use, mean (SD)	850	11.6 (22.2)	5.9 (10.2)	16.8 (28.3)	IRR: 2.85 (2.39, 3.39)	<0.001
Satisfaction at 3 months, No. (%)						
Satisfied with assigned application	712	599/712 (84%)	284/346 (82%)	315/366 (86%)	OR: 1.38 (0.92, 2.08)	0.121
Application was useful for quitting	711	552/711 (78%)	255/343 (74%)	297/368 (81%)	OR: 1.49 (1.04, 2.14)	0.031
Would recommend assigned application	734	589/734 (80%)	273/356 (77%)	316/378 (84%)	OR: 1.58 (1.09, 2.29)	0.016
Felt application was made for me	697	535/697 (77%)	242/335 (72%)	293/362 (81%)	OR: 1.67 (1.16, 2.39)	0.005

Abbreviations: IRR, incident rate ratio; OR, odds ratio; PE, point estimate.

<sup>a</sup>All models include the following covariates: education (high school diploma or less), heavy smoking (>20 cigs/day), minority race or ethnicity and depression symptoms (CESD-2016).<sup>b</sup>A full 6 months of utilization data from Google Analytics were available for n=850/863, 98%.<sup>c</sup>median = 5<sup>d</sup>median = 4<sup>e</sup>median = 8