A systematic review of smartphone applications for smoking cessation

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Cite this as: *TBM* 2017;7:292–299
doi: 10.1007/s13142-017-0492-2

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Abstract

Tobacco use is the leading cause of preventable disease and death in the USA. However, limited data exists regarding smoking cessation mobile app quality and intervention effectiveness. Innovative and scalable interventions are needed to further alleviate the public health implications of tobacco addiction. The proliferation of the smartphone and the advent of mobile phone health interventions have made treatment more accessible than ever. The purpose of this review was to examine the relation between published scientific literature and available commercial smartphone health apps for smoking cessation to identify the percentage of scientifically supported apps that were commercially available to consumers and to determine how many of the top commercially available apps for smoking cessation were supported by the published scientific literature. Adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, apps were reviewed in four phases: (1) identified apps from the scientific literature, (2) searched app stores for apps identified in the literature, (3) identified top apps available in leading app stores, and (4) determined which top apps available in stores had scientific support. Seven articles identified six apps with some level of scientific support, three (50%) were available in at least one app store. Conversely, among the top 50 apps suggested by each of the leading app stores, only two (4%) had any scientific support. While half of the scientifically vetted apps remain available to consumers, they are difficult to find among the many apps that are identified through app store searches.

Keywords

Tobacco cessation, Mobile health, eHealth, Smartphone application

INTRODUCTION

Approximately 36.5 million American adults smoke cigarettes, with statistics showing greater prevalence among those living below the poverty level [1]. While smoking has declined considerably over the past 50 years, it is still the leading cause of preventable disease and death in the USA [1–5]. Totalling more than 480,000 premature deaths annually, smoking remains a major public health concern, despite advancements to reduce tobacco-related death and disease [1, 3, 4].

Implications

Researchers: This paper will help guide future research efforts in the development and evaluation of mobile health applications for tobacco cessation by drawing attention to the scarcity of scientifically vetted mobile health apps, the difficulty in finding those which are supported by scientific evidence, and the need for a more efficient method for evaluating such technology-based health interventions.

Practitioners: This paper will help guide practitioners toward evidence-based mobile health applications when recommending mHealth and eHealth tools for their patients.

Policymakers: This paper will inform policymakers about the scarcity of proven scientifically supported mobile health applications for smoking cessation and inform decisions regarding the evaluation and regulation of such applications.

Electronic supplementary material

The online version of this article (doi:10.1007/s13142-017-0492-2) contains supplementary material, which is available to authorized users.

The Centers for Disease Control and Prevention (CDC) approximates that 70% of smokers want to quit and nearly 50% try each year. However, fewer than 10% are successful [2], likely due to the underutilization of proven treatment strategies [2, 6, 7]. Limited data exists regarding the content quality and intervention effectiveness of mobile applications (apps) for smoking cessation [8–10]. A recent content analysis of such apps revealed low levels of adherence to evidence-based treatment guidelines [9, 10]. Research is needed to identify which smoking cessation apps offer support rooted in evidence-based treatment strategies and to explore availability of such apps to smokers in need of support.

Historically, smoking cessation support services were offered in-person. While these represent an essential component of a public health approach to

tobacco, the scalability of in-person interventions is limited [8, 11, 12]. Mobile health interventions delivered via smartphone may help to alleviate this issue. There is a growing body of literature to support text message-based mobile health interventions for tobacco [13–18] which have been shown to improve user engagement with cessation programs by expanding communication through asynchronous and real-time messaging with support networks, and by reducing barriers to access such as cost, location, or timing/schedule conflicts [13–15]. However, functionality is limited to simple communication with text-based programs. While few studies have examined mobile app interventions [8, 19], smartphone apps offer many additional advantages, including interactive and customizable tools to support smokers throughout the multi-stage process of quitting tobacco, including tools for self-monitoring, progress tracking, and daily reminders, in addition to social support [8].

The PEW Research Center reports that 64% of American adults own a smartphone, and 10% rely on their phone's data plan as their only means of access to high speed internet [20]. This is true even for low-income populations, where rates of cigarette smoking are higher [1]. Exceeding the national average, 13% of Americans with an annual income below \$30,000 rely on their smartphone for internet access compared with only 1% of Americans earning over \$75,000 [20]. A study of those who use smoking cessation apps concluded that apps can reach ready-to-quit smokers who are not already receiving nor seeking professional help [11]. With the proliferation of smartphones, mobile health tools are uniquely positioned to influence these populations and show promise for ready scalability to offer tailored and interactive smoking cessation support anytime and anywhere [11].

The proliferation of the smartphone and the advent of mobile health interventions have made treatment for smoking cessation and other conditions more accessible than ever before [8]. Tobacco users can access apps in their own time, without having to leave the comfort and security of their home. Many apps are even available to users free of charge. Perceived barriers to treatment such as lack of transportation to a treatment center, schedule/timing conflict, and cost can be overcome with the use of mobile phone health interventions. Health apps offer functionality which allows users to receive reminders for health appointments and medication adherence for chronic conditions such as diabetes, while others offer accessible, real-time, monitoring and social support for behavioral health conditions such as tobacco addiction [19]. With the ubiquity of the mobile phone, and the potential for flexible treatment options to reach more people, research about health apps is on the rise, although, few studies have examined the quality of content or the effectiveness of apps promoting smoking cessation [21–27].

Health app reviews serve the medical community by identifying apps available for a specific health condition and provide a critical analysis to identify those rooted in evidence-based practice. With health apps

becoming a supplement to modern day healthcare, even within populations who may not have otherwise sought treatment for their conditions, it is vital for researchers to examine the quality and effectiveness of the apps that are available.

OBJECTIVE

The aim of this systematic review was to determine which apps designed to aid smoking cessation are rooted in evidence-based science and to determine the availability of such apps. This review examined the relation between the scientific evidence and available commercial mobile phone health apps for smoking cessation to identify the percentage of scientifically supported apps that were commercially available to consumers and to determine how many of the commercially available apps for smoking cessation were supported by scientific evidence. To achieve this goal, the app market was examined from two crucial perspectives: the healthcare provider and the consumer (the smoker). Healthcare providers are more likely than consumers to review the scientific literature to identify apps with scientific backing because most consumers do not have ready access to the literature. Without access to research literature, consumers are likely to rely upon the recommendations of online app stores when making healthcare app selections. Exploration from this dual perspective required a review of the apps from two separate starting points (1) starting from the literature and finding the identified apps in the stores and (2) starting from the app stores and comparing the available apps with the results from the scientific literature review.

METHODS

To remain consistent with other published systematic reviews of health-related apps [28], the research team followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model, an evidence-based set of criteria for reporting in systematic reviews and meta-analyses [29]. While many health apps may offer effective support rooted in valid, evidence-based treatment strategies (i.e., cognitive and behavioral therapy) while never receiving mention in a published research article, the aim of this review was to start by identifying the health apps for smoking cessation which had been vetted by the scientific community and recommended for consumer use to form a solid foundation of scientifically supported apps for smoking cessation. The review team elected to evaluate apps in line with traditional practices for evaluating behavioral health treatments, which looks to the published medical literature for guidance. Therefore, for this review, only published research articles related to an app were considered evidence of scientific support. Apps designed to facilitate smoking cessation were identified and evaluated for scientific support in four phases.

Phase 1: identified all smoking cessation apps reported in the scientific literature

A literature search was conducted using the databases MEDLINE and PsycINFO and references from relevant articles. Broad search terms were used to capture all articles relevant to the evaluation of mobile apps for smoking cessation, including those which may have been initiated during the earliest development of mobile technology. The search terms used were as follows: tobacco OR smoking AND text message OR short message service OR smartphone OR cellular telephone OR mobile phone OR personal digital assistant OR mobile app OR mobile application. Peer-reviewed articles on the topic of mHealth that were published in English between 1996 (the release date of the first palmtop computer [28]) and September of 2015 were included for review.

Two independent raters screened the abstracts of the resultant de-duplicated search and categorized into (1) obtain full article for review or (2) exclude. The two raters reviewed the full articles. During the screening of abstracts and full articles, studies about mHealth interventions for smoking were included. Excluded articles were categorized into the following exclusion categories: not mHealth, not tobacco cessation, not peer-reviewed article, not English language, clinician-facing tool, and not empirical article or review. The remaining articles were included for qualitative review. Empirical articles and systematic reviews about mobile app interventions for smoking cessation were included for phase 2 app review. Studies were rated according to level of scientific support offered for a mobile app: (1) not clearly rooted in an evidence-based approach or theory AND not subjected to any kind of study, (2) clearly rooted in an evidence-based approach or theory, but not subjected to any kind of study, (3) a pilot study of acceptability or usability but no impact on abstinence tested or demonstrated against a control condition, (4) a non-randomized controlled trial (i.e., there was a treatment protocol and control condition but subjects were not randomized into the condition), and (5) an RCT comparing the app against a treatment as usual or alternative treatment control condition. All studies falling under a quality rating of 4 or 5 were categorized based on whether the results showed the app led to non-chance improvements in abstinence. The two independent raters compared findings to achieve consensus and discrepancies were resolved by a third rater until a final list of studies pertaining to the evaluation of apps for smoking cessation was compiled.

Because mHealth app research for smoking cessation is a growing area of study, with many investigations still gaining traction, the five levels of scientific support were discussed in terms of two types of scientific evidence. (1) “Low quality evidence based” apps were defined as those with a rating of 2–4, which are supported by studies that are clearly rooted in an evidence-based approach or theory, but not subjected to any kind of study, pilot studies demonstrating only acceptability or usability, and those tested in non-randomized trials. (2) “High quality evidence based” apps were defined as those with a rating of 5, which are supported by at least one high-quality RCT suggesting positive impact on smoking cessation.

Phase 2: identified which apps from the literature review were available in the app stores

Each app identified in the scientific literature during phase 1 was searched for in each of the following online app stores: App Store for iPhone, Blackberry App World, Google Play for Android, and Windows Phone Store. Apps with the same name and developer of those listed in the literature were considered a match. A list was created to identify which apps having any scientific grounding (evidence rating 2–5) were available and which stores offered them.

Phase 3: identified the top smoking cessation apps available in the app stores

In October of 2015, the main online app stores were reviewed. The four app stores, App Store for iPhone, Blackberry App World, Google Play for Android, and Windows Phone Store, were searched to identify available smoking cessation apps. The search terms were as follows: quit smoking, stop smoking, and smoking cessation. Each search term/phrase was searched separately and all three were used for each of the four stores, totaling 12 separate searches. The number of apps returned per search was documented for each store. Apps not pertaining to the support of smoking cessation were removed. A final de-duplicated list was generated to identify the total number of unique and relevant apps offered for smoking cessation.

Phase 4: identified which apps from the app stores were supported by scientific evidence

The top 50 relevant recommended apps per search term were reviewed for the previously identified scientifically supported apps identified during phase 1, and results were documented. Only the top 50 apps were chosen for review for the sake of efficiency and to best represent real search behavior (i.e., minimize scrolling, focus on the first page of results), which is unlikely to include review of all apps available for a given health concern [30, 31].

RESULTS

Phase 1: identified all smoking cessation apps reported in the scientific literature

Following careful review of the 158 articles which met broad search criteria, only 11 met final inclusion criteria for qualitative review of app evidence (Fig. 1). Seven articles identified six apps with some level of scientific support (i.e., evidence rating of 2–5). The predominant forms of evidence found were 43% high quality and 57% low quality. High-quality evidence included three exploratory pilot RCTs with evidence suggesting positive impact on abstinence (Fig. 2). Low-quality evidence included two pilot studies of acceptability or usability, one feature-level analysis of an app, and one app clearly rooted in an evidence-based approach or theory, but not subjected to any kind of study (Fig. 2). Two of the studies focused on the same app, one study categorized as low-quality evidence and the other categorized as

Fig 1 | Literature review flow chart

high-quality evidence. Because one of the studies supporting the app qualified for high level support, the app itself was considered supported by high-quality evidence. Due to the exploratory nature of the high-quality studies, none were categorized as statistically significant with results indicating the app led to non-chance improvements in abstinence. See Supplemental Table 1 for detailed study characteristics.

Phase 2: identified which apps from the literature review were available in the app stores

Each app identified in the scientific literature was searched for by name in the major online app stores. A list was created to outline which scientifically vetted apps from phase 1 remained available to consumers and in which stores the apps could be found (Table 1). Three (50%) of the apps supported by some level of

Fig 2 | Published research about smoking cessation apps

Table 1 | Evidence-based apps for smoking cessation: availability in online app stores

App name	Apple store	Google store	Blackberry store	Windows store
SmartQuit	Yes	Yes	No	Yes
DistractMe	No	No	No	No
mCM	No	No	No	No
SmokeFree28	Yes	Yes	No	No
Craving to Quit	Yes	Yes	No	No
REQ-Mobile	No	No	No	No

evidence (evidence rating 2–5) were found to be available in the stores; however, only one was supported by high-quality evidence. Three (50%) could not be found searching by app name. Three of the four stores offered at least one app supported by some level of evidence (evidence rating 2–5); however, no apps were found to be available across all four platforms. The App Store for iPhone and Google Play for Android offered three (50%) of the apps, while only one (17%) was found in the Windows Phone Store. The Blackberry store did not offer any of the scientifically supported apps.

Phase 3: identified the top smoking cessation apps available in the app stores

During phase 3, the app stores were searched for the top relevant apps for smoking cessation using the following search terms: quit smoking, stop smoking, and smoking cessation. App Store for iPhone returned an average of 94 apps per search and, after deduplicating the final list across search terms, identified a total of 177 unique apps relevant to smoking cessation. Google Play offered an average of 97 apps per search and identified a total of 139 unique and relevant apps. Blackberry App World averaged 302 apps per search and identified a total of 70 unique and relevant apps, and the Windows Phone Store averaged 22 app suggestions per search and identified a total of 55 unique and relevant apps. The search terms “quit smoking” and “stop smoking” produced the most results. The search term “smoking cessation” returned fewer app suggestions overall.

Phase 4: identified which apps from the app stores were supported by scientific evidence

Phase 4 revealed which of the scientifically supported apps were listed among the app store search results. The top 50 apps per search term were reviewed for the previously identified scientifically supported apps to determine how many were found during keyword searches for smoking cessation apps (Table 2). Of the three supported apps found, only two, SmartQuit and Craving to Quit, were listed among the top apps by at least one app store, with only SmartQuit supported by high-quality evidence. The app SmokeFree28 never appeared among the list of top 50 apps to support smoking cessation. While the search term “smoking cessation” returned fewer app suggestions, it was the most effective search term for retrieving scientifically supported apps on the topic. The supported apps that

were available were only found when the search term “smoking cessation” was used. None of the scientifically supported apps were retrieved by using the search terms “quit smoking” and “stop smoking” (Table 2).

DISCUSSION

The aim of this systematic review was to determine which apps for smoking cessation are rooted in evidence-based science and to determine the availability of such apps. A review of 158 articles identified only six apps, 57% of which were supported by low quality evidence. A search of the popular app stores showed that only three (50%) remained available to consumers, with only two ranking among the top 50 popular apps for smoking cessation retrieved via keyword search. This suggests that while half of the few scientifically vetted apps remain available, most will be underutilized as they are unlikely to be found by consumers.

Challenges faced during the review revealed additional findings specific to the app search process. Search terms are not created equal. While plain language search terms (e.g., quit smoking, stop smoking) resulted in more app suggestions than the use of formal language (e.g., smoking cessation), the scientifically supported apps were only recommended when formal terminology was used (Table 2). Some search results were irrelevant to smoking cessation, particularly those of Blackberry App World. No correlation was found between the amount of options offered and the amount of scientifically supported apps among the selections. This highlights a disconnect between the terminology consumers use to search for health apps and the terminology app developers and app stores use to index apps. The US Department of Health and Human Services Office of Disease Prevention and Health Promotion has recommended the use of plain language in medicine as a strategy for better communicating health information and improving health literacy [32]. Their research shows that consumers are more likely to use familiar, plain language such as “quit smoking” or “stop smoking” and are less likely to use formal language, such as “smoking cessation” when searching for health information and support [32]. To make health apps easily searchable and ultimately more accessible to consumers, future research should explore ways to

Table 2 | Evidence-based apps listed among the top 50 apps recommended by online app stores

App Store:		Apple			Google			Blackberry			Windows		
Search Term:		Quit Smoking	Stop Smoking	Smoking Cessation	Quit Smoking	Stop Smoking	Smoking Cessation	Quit Smoking	Stop Smoking	Smoking Cessation	Quit Smoking	Stop Smoking	Smoking Cessation
Mobile Apps:	SmartQuit			x			x						x
	DistractMe												
	mCM												
	SmokeFree28												
	Craving to Quit			x									
	REQ-Mobile												

connect plain language search terms with the best health app options on the market. One approach might be to reach out to developers and app store indexers to work together toward (1) a plain language approach, (2) categorization and organization of apps by scientific merit/underlying medical theory, and (3) providing users with tools which refine search results and sort order to highlight science-based selections.

Evaluating the scientific merit of health apps across app-store platforms also presented several challenges. App stores vary in the quantity and quality of apps available for smoking cessation. Only three of the four app stores offered a scientifically supported app, and those which did offered one to three options with only one option supported by evidence of high quality. While Blackberry App World recommended the most apps per search ($M = 302$), compared with App Store for iPhone ($M = 94$), Google Play ($M = 97$), and Windows Phone Store ($M = 22$), Blackberry did not recommend any apps which qualified as scientifically supported. Alternatively, the Windows Phone Store recommended only one app when using the search term “smoking cessation,” but that one app was supported by high quality research.

The fact that so few apps qualified as scientifically supported through our scope of research and peer review may suggest this evaluation strategy is no longer adequate for interventions tied to such rapidly evolving technology. The design and execution of a study, followed by the time required to publish results, is a much slower process than the fast-paced timeline for app development. Future studies should consider methods better suited to address rapidly evolving technology. One alternative is to modify our approach by broadening the definition of scientific support to include apps which are consistent with evidence-based practice, but not the subject of published research. While such a review would require more app-level critical analysis by the

reviewer, it may identify a larger pool of useful smoking cessation apps linked to scientific support.

Additionally, because many apps share similar treatment elements, this modified approach could identify apps with similar functionality and underlying health theory, allowing for the evaluation of “classes” of apps rather than a potentially redundant app-level review. Data specific to technology-based interventions, including performance, evaluation, and user analytics, may serve as an additional evaluation tool for health apps, with even more data on the horizon as technology and mHealth tools continue to progress. The small number of apps classified by this review as scientifically supported serves as a foundation of recommended, science-based apps, a foundation upon which future research may build. While a literature-based approach may not be the best fit for app review, the PRISMA technique served as an effective methodology for this review and is recommended going forward.

Limitations

App review was limited by the differences between the search functions for each app store. It can be problematic to compare search results across platforms because each store uses unique and proprietary criteria for the retrieval of results and the sort order used to present them. For example, we were unable to determine if search results sorted by user-generated review vs. popularity influenced whether an app supported by published research would appear in the top apps displayed. One of the app reviewers contacted the app stores but not enough information was available to further address these differences. Future research should examine health apps within as well as across platforms.

The methods used to determine whether an app remained available to consumers were also limited. By searching the app stores for scientifically supported apps, it could only be determined if an app was available at the time of the search. This method did not

explore whether an app was previously available to consumers, either in the form studied or as an earlier version with a different name. In addition, it is possible that some vetted apps may have never been available outside the study. Future reviews should seek additional information about app availability and history.

This review defined scientific support in terms of published research, which limited the number of apps that qualified. Apps currently under investigation, and without previous mention in the scientific literature, would be excluded from review. Health apps that offer effective support rooted in valid, evidence-based research but never subjected to scientific study would also be excluded. Focusing only on published articles offers a solid foundation of apps vetted and accepted as effective by the scientific community, but does not consider the merits of many other effective and available health apps for consumers, many of which are also rooted in accepted theory. A future review might apply a broader definition of “scientific support” in their examination of apps to include any app which adheres to previously researched and accepted treatment methods, despite the lack of app-level research.

Conclusions

The mobile health app market is evolving rapidly and few of the smoking cessation apps available have been formally researched. While some apps have shown promise in small randomized trials for promoting changes in smoking, including point prevalence abstinence, none have been tested with fully powered studies [21, 22, 25]. Apparent turnover of apps, inconsistent quality, varying results between search terms, and irrelevant app suggestions are significant barriers for consumers seeking scientifically supported health apps. The CDC suggests one barrier to cessation success is the underutilization of recommended and proven treatment strategies [2, 6, 7]. The current market of mobile apps for smoking cessation is not helping to reverse this trend.

The challenges faced during this review suggest that the time-consuming rigor of traditional research and peer review may not be the most efficient method for evaluating the scientific merit of apps. The irreconcilable timelines of fast-paced app development and the slower-paced scientific method call for the creation and adoption of a new approach to app evaluation. An approach with efficient standardized evaluation strategies that allow researchers to evaluate apps based upon underlying theory rather than individual app-level analysis would streamline the process and may help researchers pick up the pace. Future studies should aim to (1) develop and standardize an innovative and timely approach to evaluate apps for commitment to evidenced-based practice, (2) explore strategies to make scientifically supported apps easily searchable and more accessible to consumers, including indexing with plain language terminology, and (3) to explore ways to inform the

development of health apps to better align app content with evidence-based medicine.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Research involving human participants and/or animals: This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: For this type of study formal consent is not required.

Previous reporting of data: The findings reported have not been previously reported or published and the manuscript is not being simultaneously submitted elsewhere.

IRB approval: This paper is a review of published data and is exempt from IRB review.

Primary data access: The authors have full control of all primary data and that they agree to allow the journal to review the data if requested.

Funding: This study was funded through internal department funds.

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