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gOPINION

EDITORIAL VIEWPOINT

Role of Mobile Phone Technology in Tobacco Cessation Interventions

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The health benefits of tobacco cessation are well established [1]. Cessation is a key element within the World Health Organization's (WHO) MPOWER strategies (*Monitoring* tobacco consumption and the effectiveness of preventive measures; *Protect* people from tobacco smoke; *Offer help* to quit tobacco use; *Warn* about the dangers of tobacco; *Enforce bans* on tobacco advertising, promotion, and sponsorship; and *Raise taxes* on tobacco) that are intended to assist in the country-level implementation of WHO's Framework Convention for Tobacco Control guidelines. The potential impact of cessation interventions in low- and middle-income countries is considerable given the large numbers of tobacco users and relatively low quit rates when compared with high-income countries [2].

Traditional tobacco cessation programs include both population-based and individual strategies. Research evidence supports the effectiveness of clinic-based tobacco cessation interventions such as physician-delivered tobacco cessation advice [3], group therapy [4], individual counseling [5], self-help materials [6], telephone counseling [7], and nicotine replacement therapy [8]. However, these strategies are found to be resource-intensive, requiring dedicated professional support and participant adherence. In addition, these methods cover only a small group of the smoking population. Systematic reviews have identified community-based interventions and mass media campaigns as an effective way to disseminate antitobacco messages to wider population groups and to reduce tobacco use, but these interventions need to be sustained to be effective, which can be costly [9,10]. Given the growing burden of the tobacco epidemic in the low- and middle-income countries, there is an urgent need for a cost-effective innovative communication media to deliver tobacco prevention and cessation services at the population level. This review aims to summarize the evidence on the effectiveness of mobile phone technology in tobacco cessation, the theoretical basis of mobile-based interventions, and the scope of mobile technology as a tool for population-based tobacco cessation interventions.

THE REACH AND SCOPE OF MOBILE TECHNOLOGY FOR HEALTH IMPROVEMENT

Mobile phones became an integral part of daily life even in low-income nations. According to the International Telecommunication Union, there are close to 5 billion mobile phone subscriptions worldwide with over 70% of users residing in low- and middle-income countries and over 85% of the world's population is now covered by a commercial wireless signal [11].

Mobile phones support a number of communication functions. Voice and short message services

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(SMS) enable 2-way communication in real time or near-real time. Most mobile phones now have a built-in camera. Pictures and short-duration videos captured using mobile phone cameras can be downloaded to one's computer or transmitted to others. With the advancement of technology, storage and processing capabilities of mobile phones also have increased. The data in a mobile phone can be transmitted in a variety of forms, including text, numerical, graphic, audio, and video files. The introduction of smart phones has extended the scope of mobile phone from a simple communication device to the level of personal computers. In contrast to digital divide, which arguably limited the reach of computer and Internet-based health behavior interventions to upper socioeconomic groups, mobile phone use has been widely adopted across socioeconomic and demographic groups and appears greater among those populations most in need of these interventions [12,13]. Technical capabilities of mobile phones combined with its personal nature can reduce the barriers of communication and increase acceptance of phone-based health interventions.

Mobile phones are currently used for public health interventions in both developing and developed countries. Mobile health interventions in developing countries are focused primarily on communicable disease control interventions (e.g., human immunodeficiency virus, malaria) and maternal and child health initiatives. SMS have been used to raise health awareness. In developed countries, mobile health interventions have been attempted in much broader areas such as smoking cessation [14,15], diabetes education [16,17], patient follow-up in a primary-care setting [18], and chronic disease management [19,20]. It is likely that the use of mobile phones in health interventions will continue to grow as they become even more ubiquitous and as technological advances increase the number of applications and functions available.

EFFECTIVENESS OF INTERVENTIONS USING MOBILE TECHNOLOGY ON TOBACCO CESSATION

A recent Cochrane review on mobile phone technology for smoking cessation concluded that trials involving text message programs showed a significant increase in short-term self-reported quitting. When the data from the text message programs and combined Internet-mobile phone programs were pooled, statistically significant increases in both short- and long-term self-reported quitting was observed [21]. However, there is a paucity of research studies in low- and middle-income countries on the feasibility, acceptability, and effectiveness of mobile phone-based interventions for smoking cessation.

Most studies on mobile-based tobacco-control interventions for smoking cessation were carried out in New Zealand, Norway, the United Kingdom, and the United States, ranging from small pilot and quasi-experimental studies [22–24] to randomized controlled trials [14,15,22,25,26] (Table 1). These studies used multiple methods for broadcasting smoking cessation messages—for cessation advice and motivational messages—using standard SMS, voice messages, interactive voice response functions, and mobile- and Internet-based message delivery. Some studies, which entirely relied on mobile technology, used standard text messages as the medium for broadcasting smoking cessation messages [14,15]. Advanced mobile functionalities such as video messages [22] and interactive voice response [25] along with the standard SMS have also been attempted for smoking cessation. Another study combined Internet and mobile technology along with pharmacotherapy—a nicotine replacement therapy [26].

Most of the randomized controlled trials of mobile-based smoking cessation were small pilot studies with very short follow-up periods [22,25,26]. But 2 randomized controlled trials, carried out by Rodgers et al. [15] in New Zealand and Free et al. [14] in the United Kingdom were well conducted and had a considerably larger sample size. These 2 trials were similar in their content as well as method of delivery. In both studies, people wanting to quit who owned a mobile phone were randomized to intervention and control arms. Apart from the regular personalized quit advice or motivational SMSs, both programs offered an interactive platform to the participants through a number of polls and quizzes. The novel "Quit Buddy" concept (which encouraged participants to text other trial participants) used in both trials provided an opportunity for social support [14,15]. In addition, the participants could request additional text messages on demand to help beat cravings. The New Zealand trial demonstrated a significant quit rate at 6 weeks in the intervention arm compared with quit rates in the control group (28% vs. 13%). The Smoking Cessation Support Delivered via Mobile Phone Text Messaging Trial (txt2stop Trial) demonstrated a similar relative benefit at 6 months (10.7% txt2stop vs. 4.9% control group).

Table 1. Mobile-based interventions for smoking cessations

Author (year); location	Summary of intervention	Sample size	Summary of intervention results
Rodgers et al. (2005); New Zealand [15]	Intervention group received regular, personalized text messages providing smoking cessation advice, support, and distraction (e.g., general interest, sports, fashion, trivia, travel). Control group participants only received 1 text message every 2 weeks, which were unrelated to smoking cessation.	Intervention group: 852 Control group: 853	Statistically significant high quit rate at 6 weeks in the intervention group versus the control group (28% vs. 13%).
Brendryen et al. (2007); Norway [25]	The intervention group received Internet- and cell-phone-based intervention for 54 weeks, consisting more than 400 contacts by e-mail, Web pages, interactive voice response, and SMS. The control group received a self-help booklet. Additionally, both groups were offered free NRT.	Intervention group:197 Control group: 199	Participants in the intervention group reported clinically and statistically significantly higher repeated point abstinence rates than control participants did (22% vs. 13.1%). Improved adherence to NRT and a higher level of post-cessation self-efficacy were observed in the intervention group compared with in the control group.
Brendryen et al. (2008); Norway [26]	Same as Brendryen et al. (2007), but NRT was not offered to both the groups.	Intervention group: 144 Control group: 146	Participants in the intervention group reported clinically and statistically significantly higher repeated point abstinence rates than control participants did (20% vs. 7%).
Riley et al. (2008); United States [31,32]	Observational study was conducted among daily smokers on a college campus.	$N = 31$	42% abstinence rate in 6 weeks on biochemical verification.
Whittaker et al. (2008); New Zealand [27]	It was a pilot study to test the content as well as the feasibility of a mobile phone-based smoking cessation intervention. Participants received video and text messages for smoking cessation, over a period of 6 months.	Pre-testing: 41 Pilot study: 15	Pre-testing confirmed the importance of selecting "real" and "honest" role models with believable stories, and animations for smoking cessation. Thirteen of 15 participants were available for follow-up and 9 participants (60%) stopped smoking during the program.
Zbikowski et al. (2008); United States [30]	An evaluation study was conducted among the participants who enrolled in the Free and Clear Quit For Life Program (a commercially available, integrated phone/Web program across the United States) between May 2006 and October 2007.	$N = 11,143$	Phone services were used more than Web services were. Women were more adherent to the overall program. Older smokers (>26 years) and moderate smokers (15 to 20 cigarettes/day) used the services more than the others did. Thirty-day quit rates at the 6-month follow-up were 41% using responder analysis and 21% using intent-to-treat analysis.
Haug et al. (2009); Germany [23]	Participants were randomly allocated to 1 of 3 study groups: 1) control; 2) intervention with 1 weekly SMS feedback; 3) intervention with 3 weekly SMS feedbacks. Individualized SMS feedbacks were based on data from the baseline assessment and a weekly SMS assessment of the stages of change according to the transtheoretical model. The control group received no intervention.	1 SMS group: 50 3 SMS group: 60 Control group: 64	No significant differences between the 3 study groups were observed in terms of examined smoking variables such as, for example, number of cigarettes smoked per day, 24-h quit attempt during study period. The acceptance of the program did not differ between the intervention groups and support intensity did not affect the acceptance of the program.

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Table 1. continued

Author (year); location	Summary of intervention	Sample size	Summary of intervention results
Whittaker et al. (2011); New Zealand [22]	The intervention group received an automated package of video and text messages over 6 months that was tailored to self-selected quit date, role model, and timing of messages. Extra messages were available on demand to beat cravings and address lapses. The control group also set a quit date and received a general health video message sent to their phone every 2 weeks.	Intervention group: 110 Control group: 116	This study was not able to demonstrate a statistically significant effect of the complex video messaging mobile phone intervention compared with simple general health video messages via mobile phone.
Free et al. (2011); United Kingdom [14]	Intervention group received motivational and behavioral change text messages, while the control group received messages unrelated to smoking cessation.	Intervention group: 2,915 Control group: 2,885	Biochemically verified continuous abstinence at 6 months was significantly increased in the intervention group (10.7% in intervention group vs. 4.9% in the control group), and the same results were obtained in the intension-to-treat analysis (9% vs. 4%).

NRT, nicotine replacement therapy; SMS, short message services.

The Happy Ending Trial [26] in Norway involved a single fully automated, intense 1-year smoking cessation program delivered via both the Internet and the mobile phone. The intervention arm included e-mail reminders, educational SMS, interactive voice response messages, and Web-based tobacco cessation support. Nicotine replacement therapy was offered to participants in both intervention and control arms. The trial reported clinically and statistically significantly higher repeated point abstinence rates (22.3% vs. 13.1%), improved adherence to nicotine replacement therapy, and a higher level of post-cessation self-efficacy in the intervention group at 1, 3, 6, and 12 months after cessation. A later trial by the same research group, which included similar intervention components but did not include the provision of nicotine replacement therapy, reported a similar improvement in the quit rate (20% vs. 7%) at 1, 3, 6, and 12 months after cessation [25]. The results from both studies suggest that psychological support for smoking cessation can be effectively mediated through mobile- and Internet-based interventions.

Complex and individually tailored mobile phone interventions were found to be less effective in promoting cessation than generic, simple phone interventions [22,27]. Whittaker et al. [22] designed a theory-based intervention comprising an automated package of video and text messages over 6 months, which was tailored to self-selected quit date, role model, and timing of messages. Extra messages were also available on demand to beat cravings and to address lapses. However, this trial was not able to demonstrate a statistically significant effect of the complex video messaging mobile phone intervention compared with simple general health video messages via mobile phone.

Mobile phones provide the opportunity for incorporating user input-based tailoring of smoking cessation interventions, which could improve the acceptance of the intervention particularly among youngsters. This was attempted in a pilot trial carried out at the University of Greifswald in Germany [28]. Although the results were not promising, this may be due to the small number of participants. Further evaluations of this approach are required to assess the utility of this method.

It is important to assess the impact of mobile phone interventions on known socioeconomic status disparities in tobacco use. However, only a small number of studies have examined this. Haug

et al. [28] examined the effectiveness of a SMS-based intervention delivered to 33 socially deprived young adults from an institution for occupational rehabilitation in Germany delivered over 12 weeks. Participants could request SMS support whenever they suffered from withdrawal symptoms or cravings. Although none of the participants reported abstinence after the intervention, before-and-after comparisons revealed a reduction in the number of cigarettes smoked per day and an increase in risk perception. A mobile phone-based counseling intervention delivered to 20 patients infected with the human immunodeficiency virus at a primary care clinic in Texas over a 2-week period reported 75% abstinence from smoking at 2-week end-of-treatment [29].

HEALTH SYSTEM APPLICATIONS

The versatility and high levels of accessibility of mobile phone technologies provide enormous potential for their use in primary healthcare settings. The health workers at the community level can screen individuals for tobacco and other risk factors using the mobile phone-based applications in order to develop local databases in primary care settings. Such information could be invaluable for planning tobacco-control programs at the state/provincial and national levels.

SCALABILITY OF INTERVENTION

As a mode of wider dissemination of public health messages, SMS could be a cost-effective way to address a large group of the population, regardless of locations and personal characteristics. The ability to tailor messages to the target audience, real-time delivery of messages, and the ability to link the user with others for social support makes mobile phones an ideal tool for tobacco cessation interventions.

Evaluation of a small number of scaled-up interventions suggests that these may have a beneficial impact on tobacco cessation. For example, the Free and Clear Quit for Life Program is a commercially available, integrated phone/Web program that is widely available through quit lines, health plans, and employers across the United States. This telephonic smoking cessation program includes proactive phone-based counseling, an interactive Website, and printed quit guides. Evaluation of experience of 11,143 enrollees of Free and Clear Quit for Life Program between May 2006 and October 2007 showed that participants used the phone services more than the Web services. Thirty-day quit rates at the 6-month follow-up were 41% using responder analysis and 21% using intent-to-treat analysis. Women and older smokers were more adherent to phone-based interventions [30].

BEHAVIOR CHANGE MECHANISM

The basis for many of the behavior change interventions in public health have been health behavior theories and models such as the Health Belief Model, Relapse Prevention, Theory of Planned Behavior, Social Cognitive Theory, the Transtheoretical Model, and Self-Regulation and Self-Determination Theory [31] (Table 2). Most of the mobile-based tobacco cessation interventions mentioned in this review have a theoretical basis for their intervention design. The theory of the Self-Regulation and Social Cognitive Behavioral Model are the basis for most of the interventions [15,22,25,26,32]. The Transtheoretical Model was used in interventions designed by Obermayer et al. [24] and Riley et al. [32] to adapt the content of the text messages to the preparation, action, and maintenance stages of the quit process. Transtheoretical Model-based messages were tailored to adapt to the high-risk situation and the stage of change. Two large randomized controlled trials of mobile SMS for smoking cessation did not cite any of the conventional behavioral theories to support their interventions [14,15].

Behavioral change theories are predominately linear and static in nature, which limits their ability to guide interventions that are dynamic and adaptive [31]. For example, the content and timing of mobile phone-based behavioral change interventions are mostly driven by a range of varying factors: (1) frequency, duration, and intensity of the target behavior; (2) socioenvironmental and psycho-physiological states of the individual; and (3) the effect of prior interventions on target behavior. Therefore, health behavior theories and models having dynamic, regulatory system components must be used to develop and explain such adaptive interventions delivered through mobile phones [30].

OPPORTUNITIES

Self-monitoring is an essential component of smoking cessation. It requires individuals to re-

Table 2. Theories of behavioral change

Health Belief Model (HBM)

HBM is one of the first theories of health behavior developed in the 1950s. The model suggests that the likelihood of an individual taking action for a given health problem is based on the interaction among 4 key variables, they are:

(1) Perceived threat, which consists of two components:
- Perceived susceptibility: people believe they can get the ill effects of smoking
- Perceived severity: people believe that the consequences of the ill effects are significant enough to try to avoid smoking

(2) Perceived benefits: people assess the positive consequences of adopting smoking cessation

(3) Perceived barriers: people identify their personal barriers to tobacco cessation and explore ways to eliminate or reduce these barriers

(4) Cue to action: events either bodily or environmental that motivate people to take action. For example, reminder cues for action in the form of incentives or reminder messages (SMS).

Transtheoretical Model (TTM)

Also known ''Stages of Change,'' the model was developed in the 1980s for smoking cessation. The model's fundamental premise is that behavior changes occur in 5 stages:

(a) *Pre-contemplation*—not intending to quit smoking in a planned duration (say next 6 months)
(b) *Contemplation*—intending to quit smoking in the next 6 months
(c) *Preparation*—intending to quit. For smokers, this may involve a mental preparation for quitting. They may plan ahead by setting a quit date and marking it on the calendar. They may also tell others about their quit date so that they have some accountability from others.
(d) *Action*—change in behavior. This is when the quit date arrives and the smoker stops smoking. If the action stage occurs and the behavior change is not maintained, then people fall back into a previous stage.
(e) *Maintenance*—this is where one maintains the changed behavior (smoking cessation) and incorporates the new behavior as a way of life *Theory of Planned Behavior (TPB).* This theory explores the relationship among behavior and beliefs, attitudes, intentions, and perceived control. Behavioral intention is influenced by a person's attitude toward performing a behavior and by beliefs about whether individuals who are important to the person approve or disapprove of the behavior (subjective norm). The TPB includes ''perceived behavioral control.'' For example, a smoker decides to quit smoking, but anticipates withdrawal symptoms. However, he or she is confident that by engaging in any other activities such as yoga or cycling will help in overcoming the withdrawal symptoms.

Social Cognitive Theory (SCT)

This theory evolved from research on Social Learning Theory, which asserts that people learn not only from their own experiences, but also by observing the actions of others and the benefits of those actions. According to SCT, factors such as self-efficacy, individual goals, and outcome expectancies determine the behavior. SCT says each behavior witnessed (smoking behaviors of elders/role models) can change a person's way of thinking (cognition). Similarly, the environment one is raised in may influence later behaviors (e.g., ease of availability of tobacco products, absence of stringent antitobacco laws).

Self-Determination Theory (SDT)

According to this theory, maintenance of behaviors over time requires that people internalize values and skills for change, and that they experience self-determination. The theory further argues that by maximizing the patient's experience of autonomy, competence, and relatedness in healthcare settings, the regulation of health-related behaviors are more likely to be internalized, and behavior change will be better maintained.

Self-Regulation Theory (SRT)

According to this theory, a self-regulating person controls and manages his or her reactions and behavior to achieve goals despite changing conditions and priorities. Behavior and outcomes are aspects of self-regulation that we can observe, but there are always many implicit and unobservable influences such as the person's perceptions and emotional state.

Adapted, with permission, from Davies M, Macdowall W. Health Promotion Theory. Maidenhead, United Kingdom: Open University Press, 2005.

cord their own smoking behavior patterns (e.g., number of cigarettes, frequency), time, place, activity, mood, and level of desire for smoking. Mobile phone applications for self-monitoring could be achieved by means of quickly self-documenting complex behaviors and using sensors to log real-time behaviors and physiological states influencing the smoking behavior of the individual. By integrating such real-time assessment and intervention, we may be able to deliver real-time tailoring of the intervention. For example, algorithms that make use of computing capabilities of mobile phones may be able to detect behavioral/biological patterns. For example, mobile phones with biosensors could identify one's smoking frequency, factors that warn of a smoking craving long before a person who is attempting to quit smoking has recognized it, and direct action to avoid or defuse the craving [33]. The technology for such developments has yet to evolve.

CONCLUSIONS

Tobacco use is a major public health concern. Mobile phones appear to be a valuable tool for the delivery of smoking cessation interventions, even to historically hard-to-reach groups due to high penetration of mobile across all socioeconomic groups. Current evidence supports the short-term efficacy of mobile phone-based intervention in smoking cessation. More rigorous studies testing the long-term effects of mobile phone interventions are needed in both high- and low-income countries to establish their effectiveness. Further research is needed particularly in the developing world to assess both their cost and cost-effectiveness. It is important that future studies describe the likely mechanisms through which the mobile-based interventions work. In summary, the rapid advances in mobile technologies, continued growth in coverage of cellular networks could open up new opportunities for tobacco prevention and control.

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