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Effectiveness of electronic aids for smoking cessation

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Abstract

Tobacco use continues to be the leading cause of preventable death in the world, and though current evidence-based approaches have substantially reduced rates of smoking, these rates remain disturbingly high. Two recent technological advancements, the electronic cigarette (e-cigarette) and mobile health (mHealth) interventions, may offer smokers an alternative way to quit smoking. E-cigarettes continue to be fiercely debated. Preliminary evidence suggests that e-cigarettes are likely much safer than regular cigarettes and are helpful to some smokers as a means of reducing or quitting smoking. Questions, however, still remain as to how they will affect overall public health—if they will be used as a "gateway" product or reduce motivation to quit smoking, to name but a few. Similarly, mHealth interventions appear to be effective and accepted by users. However, mobile 'apps' have yet to be tested in randomized trials and there are concerns about violations of users privacy and state jurisdictions.

Keywords

Electronic cigarettes; mHealth; electronic interventions; smoking cessation

Introduction

Tobacco use continues to be the leading cause of preventable and premature death, killing an estimated 443,000 Americans each year and costing the nation $193 billion in medical costs [1,2]. Smoking increases the risk of decreased lung function, coronary heart disease, and stroke [3,4]. Cigarette smoke contains more than 7,000 compounds, at least 60 of which are known human carcinogens linked to an increased risk for 18 different types of cancers, such as kidney, liver, leukemia and cervical [1,4]. Unfortunately, the negative effects of smoking are not limited to the smoker; it estimated that 600,000 non-smokers will die from exposure to secondhand smoke each year worldwide [5].

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Compliance with Ethics Guidelines

Conflict of Interest

Ellen Meier, Alayna P. Tackett and Theodore L. Wagener declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

Current evidence-based approaches, though helpful, do not appear to be enough to substantially reduce the number of current smokers nor the growing number of smokers worldwide [6, 7, 8, 9]. Rates of cigarette smoking among U.S. adults continue to remain disturbingly high at 19.0% [7]. Even in developed countries with comprehensive tobacco control efforts, reductions in smoking and tobacco use are beginning to level off [10].

Recent technological advancements have led to two very different types of "electronic aids to cessation" that may offer new approaches to reducing tobacco-related morbidity and mortality: the electronic cigarette (e-cigarette) and mobile health (mHealth) interventions. These two interventions have the potential to reach smokers who would not normally utilize traditional services and smokers for whom traditional services might have failed. Although these two methods differ in their nature, they both serve as an alternative way to quit smoking that may be more appealing to many smokers and contribute to the overall goal of reducing tobacco-related deaths.

The Electronic Cigarette

In 1965 a "smokeless non-tobacco cigarette" similar to the current e-cigarette's design and function was patented and purposed as a "safe and harmless means" for smoking; however, it wasn't until recently that such devices became well-known [11]. In 2004, the Chinese group, RUYAN (Dragonite International), developed and patented the e-cigarette [12], an electronic nicotine delivery system (ENDS) designed to deliver nicotine to the respiratory system via a tobacco- and combustion-free inhalation process [13,14]. The e-cigarette generally has three segments; a plastic cartridge for the user to inhale through, a re-chargeable battery and a reservoir-vaporizing chamber, which contains an "atomizer" (i.e., heater) to vaporize the nicotine-containing liquid [14]. Typically, an LED light is placed on the tip of the e-cigarette to indicate inhalation to the user [13]. Modeled to visually mimic a traditional tobacco cigarette, the e-cigarette vaporizes very small quantities of nicotine dissolved in propylene glycol or vegetable glycerin through the use of microelectronics [14, 15]. The nicotine cartridge is designed to last approximately 300 – 350 puffs (Dragonite International) [14,15].

In 2009, the Family Smoking Prevention and Tobacco Control Act (FSPTCA) granted regulation authority of e-cigarettes to the U.S. Food and Drug Administration. Given that e-cigarettes currently do not make any therapeutic claims, they are categorized as a tobacco product not a smoking cessation aid [16]. Despite progress towards some regulation, there is still much debate surrounding the risks and benefits of the e-cigarette [17,18,19,20].

Currently, three types of e-cigarettes exist: 1) replaceable cartridge type, 2) 'cartomizer,' type, and 3) 'tank' systems. The replacement cartridges are comprised of saturated foam that contains glycerol or propylene glycol, flavoring, and varying amounts of nicotine [21,22]. 'Cartomizers' types combine both the cartridge and 'atomizer' into one piece [21,22]. The 'tank' system is a more advanced type of 'vaping' that contains a fluid-filled reservoir different from the standard foam replacement cartridge [21]. All three systems/types come in a range of flavors and nicotine strengths. Flavor choices can include fruits, candy, traditional tobacco flavor, or a personalized mixture (only for tank systems). Both 'cartomizers' and 'tanks' allow the user to apply different battery voltages, which in turn affects 'vaping', by manually controlling the voltage that is applied to the 'atomizer' [21,22]. After the initial cost of purchasing the equipment (~$50–$70), tank system vaping is cheaper than both cartridge and cartomizer types, and all three are cheaper than smoking regular cigarettes [23]. Moreover, anecdotal reports from vapers indicate that tank systems deliver a more satisfying experience: 1) stronger "throat hit" from the vapor, 2) better craving reduction, 3) longer battery life and 4) better flavors.

E-cigarette User Profiles

Almost 70% of individuals have heard of e-cigarettes, greater than 7% have tried them, and less than 3% of individuals are current users [24,25]. Most e-cigarette users report using because they consider them to be less harmful than regular cigarettes (79.8%), to reduce smoking regular cigarettes (75.4%), or to quit smoking all together (85.1%)[24]. E-cigarette users report initiating use because they want an alternative to smoking (76%), for health reasons (6%), cost (3%), and to smoke in places where regular cigarettes are banned (3%) [21]. Among college students, those who are of Greek membership, have used hookah, binge drink, or have a history of drug use are more likely to have tried e-cigarettes [26]. More men than women tend to use e-cigarettes, prefer tank systems, and prefer tobacco flavors, whereas women prefer sweet flavored liquids [21]. E-cigarette users report few side effects, improved cough and breathing, and waiting longer until their first ‘vape’ in the morning, suggesting improved quality of life and lower nicotine dependence [21].

Biological effects

Present concerns about the biological effects of e-cigarettes include its potential adverse effects on pulmonary function, whether they contain toxic chemicals and secondhand vapor exposure. Findings are mixed as to whether e-cigarettes produce changes in lung function. In a study using a cigarette control group, e-cigarettes did not produce significant changes in lung function, whereas regular cigarettes did [27]. Alternatively, e-cigarettes have been shown to produce an increase in airway resistance after 5 minutes of use; however, this study lacked a cigarette control group [28]. Initial studies examining the chemical constituents of e-cigarette vapor, suggest that compared to regular cigarettes, e-cigarettes have 9–450 times lower levels of compounds that are potentially toxic to humans, and for some compounds, similar levels as the prescription nicotine replacement therapy inhalator [29]. Furthermore, there appears to be variability in the nicotine delivered from e-cigarettes, with some producing far less than as labeled, but generally, delivering nicotine as labeled [30,31,32]. Blood absorption of nicotine in e-cigarettes compared to regular cigarettes has also been a focus of research. In clinical laboratory studies, naïve e-cigarette users tend to need more puffs of an e-cigarette to obtain serum cotinine levels similar to regular cigarettes [27,33] but experienced users do not [34]. Therefore, it appears as though practice with e-cigarettes may improve the puff efficiency. Finally, like secondhand smoke, large amounts of laboratory produced secondhand vapor exposure results in high levels of nicotine for exposed individuals. However, it is unclear whether real world levels of secondhand vapor exposure would result in such elevated nicotine levels. Alternatively, secondhand vapor exposure does not appear to significantly change lung function [27].

Taken collectively, current research suggests that while not harmless, e-cigarettes are likely, if not surely better for individual health if completely substituted for smoking regular cigarettes. Regarding public health, the effect of long-term e-cigarette use and exposure to secondhand vapor on lung function is still debated.

Effects on Withdrawal Symptoms

E-cigarettes appear to significantly reduce cigarette cravings and withdrawal symptoms [33, 34]. Although nicotine absorption takes longer in naïve users, both naïve and experienced e-cigarette users report decreased cravings and urges to smoke after using an e-cigarette [21,33,35]. Moreover, Bullen and colleagues [35] found that a nicotine-free e-cigarette was able to effectively reduce craving and number of cigarettes smoked, suggesting that the e-cigarette provides a behavioral replacement for smoking by mimicking many of the aspects of smoking which is not true of current FDA approved nicotine replacement products (i.e., nicotine gum, patch, inhaler or lozenge). Additionally, gender differences exist with reported e-cigarette effects; while effective for women in improving depression and concentration, e-

cigarettes appear to be less effective at reducing irritability and restlessness, compared to men [36]. However, given the tendency towards lower tolerance of weight gain following smoking cessation in women than in men [37], weight management may turn out to be another gender specific effect of e-cigarettes. Evidence from one qualitative study suggested that some women use the nicotine-free e-cigarette to reduce food cravings following smoking cessation as a form of weight management [22].

Effects on Smoking Behavior

To date, a handful of preliminary studies indicate that e-cigarette use leads to significant reductions in total number of regular cigarettes smoked with some smokers achieving total abstinence from nicotine [38,39,40]. In a small uncontrolled, clinical trial of smokers uninterested in quitting, e-cigarettes were effective in helping a majority of smokers reduce or completely quit regular cigarettes [40]. Specifically, at the 24 week follow-up, 22.5% of smokers had quit regular cigarettes for at least 30 days, 12.5% had reduced their regular cigarette use by 80%, and 32.5% had reduced by at least 50%, leaving only 20% of smokers who did not make significant reductions. Additionally, three participants (7.5%) were no longer using any nicotine or tobacco products, suggesting that e-cigarettes can potentially be helpful in overall nicotine cessation. Interestingly, smokers in this study were not provided a cessation message and were not encouraged to substitute e-cigarettes for smoking; instead, they were simply told to use the e-cigarette *ad libitum*.

Similarly, in a double-blind, randomized control trial, in which uninterested smokers were instructed to use either a 7.2 mg, 5.4 mg, or non-nicotine containing e-cigarette *ad libitum*, 11.6% of smokers (32/300) had remained quit at 12-weeks and by 52-weeks, 8.7% of smokers (26/300) had remained quit, with 26.9% (7/26) continuing to use e-cigarettes [39]. Additionally, 13.7% of smokers (41/300) had reduced their cigarettes per day by at least 50%, resulting in 19% of smokers (57/300) reducing or quitting regular cigarettes. At 52-weeks, reduction rates did not differ significantly between e-cigarette groups; however, quit rates were significantly higher among nicotine containing e-cigarettes users. Surveys of current e-cigarette users have supported these findings showing abstinence rates from regular cigarettes over the past “several months” at rates as high as 74% [21] to 96% [41]. It is important to note, however, that a majority of those who completed these surveys were a self-selected sample of visitors to various e-cigarette websites and discussion forums. Therefore, though these results are positive, they should be interpreted with caution.

Similar reductions in cigarette smoking were seen in a sample of smokers diagnosed with schizophrenia, a population with high rates of smoking, for which traditional medications (i.e., Bupropion and Varenicline) come with strong warnings for use due to their potential negative side effects (e.g., psychiatric symptoms and suicidal ideation)[42]. At 12 months, 14.3% of individuals self-reported quitting regular cigarettes, and half reported at least a 50% reduction in cigarette smoking, resulting in a 64.3% overall reduction of cigarette smoking within the entire sample [38]. Therefore, preliminary evidence suggests that e-cigarettes may be an effective quit or harm reduction tool for historically difficult smoking populations.

Despite the e-cigarette’s relatively recent introduction to the U.S. market, significant and important research has been conducted examining not only the chemical constituents of e-cigarette vapor but also the biological and behavioral repercussions of e-cigarette use (see Table 1 for a sample of past year’s studies examining e-cigarettes). It is important to note, that current trials examining the effectiveness of e-cigarettes as smoking cessation aids have only examined those uninterested in quitting (i.e., a less motivated population) and have only provided *ad libitum* instructions to study participants. Future trials may likely see even

higher rates of quitting with the e-cigarette if researchers begin to examine the effectiveness of these devices among the motivated and/or provide a smoking cessation message.

mHealth for Smoking Cessation

Advancements in mobile technologies provide opportunities for smoking cessation interventions to be delivered via cell phone. Mobile health interventions include text or video messages, applications or "apps" centered on improving health behaviors [43]. This type of intervention may have the potential to provide brief treatment options for many smokers who may have not been otherwise reached with traditional methods. The U.S. National Cancer Institute's smokefreeTXT program is one example of a mobile phone intervention for smoking cessation that relies on text messages to send brief advice, motivational messages and offer an opportunity for smokers to self-monitor their progress [43]. In 2011, the Community Preventive Services Task Force [44] recommended the use of text-based interventions given their evidence for potential effectiveness.

Effectiveness as a Cessation Tool

Text-message based smoking interventions appear to be effective in initiating quit attempts and abstinence in the short-term [45,46,47]. However, present research demonstrates inconsistent outcomes for long-term effectiveness [45, 48] and no studies exist comparing established programs to each other. Regardless of these discrepancies, smokers generally view text-message interventions as a convenient alternative to traditional interventions [49].

Txt2stop is one personalized interactive program that sends text-messages to smokers attempting to quit and serves as a lapse recovery program [50,48]. Smokers receive motivational messages, advice, and reminders relevant to their own quit plan (e.g., 'Cravings last less than 5 minutes on average. To help distract yourself, try sipping a drink slowly until the craving is over.'). In a randomized control trial, Txt2stop resulted in significantly more smokers becoming abstinent for 6 months (10.7%) compared to a control group (4.9%) as confirmed by blood or urine? cotinine levels [48]. Additionally, 38.5% of smokers utilized the interactive features of the program by texting "crave" or "lapse" to request support [50].

OnQ is a similar interactive mobile phone program [45]. In a randomized control trial comparing the onQ program to a control, the onQ users reported significantly higher sustained abstinence rates for the past seven days (21.4%), than those in the control group (15.2%) at a one-month follow-up. These differences were no longer significant at the 6 month follow-up, suggesting that the onQ program may result in short-term effects for smoking cessation, but the effects do not appear to be long-term.

Other studies have produced inconclusive results about the additive effects of certain features. For example, a video coach does not seem to be more effective than standard text messages [51] and sending smokers more text-messages does not increase their likelihood of reducing cigarettes smoked, making a quit attempt, or increasing self-efficacy [52]; however, both of these studies were pilot studies and were statistically underpowered. See table 2 for a sample of mhealth studies over the last several years.

Smartphones

Through the use of 'apps', smartphones are more advanced in their ability to offer interactive components for smoking cessation compared to traditional text-message mHealth interventions [53]. To date, no studies have examined the effectiveness of Smartphone apps for smoking cessation despite the high number of existing smoking cessation apps. Most apps do not adhere to the U.S. Public Health Service's 2008 Clinical Practice Guidelines for

Treating Tobacco Use and Dependence [54], suggesting that many apps may not be helpful at reducing smoking; however, research is needed to determine their effectiveness.

Considerations and future directions

Technologies such as e-cigarettes and mHealth offer several benefits compared to traditional interventions; however, it is important to consider the potential negatives of such advancements. There are several unique considerations for e-cigarettes and mHealth.

E-cigarette opponents argue for a number of safety concerns including manufacturers' quality control, the safety of repeated exposure to e-cigarette constituents (e.g., propylene glycol), and the risk of nicotine overdose from children drinking refill bottles of e-cigarette nicotine liquid [17]. Many individuals argue that e-cigarettes may decrease motivation to quit smoking, only replace regular cigarettes, act as a "bridge product" for individuals to use in places where cigarette smoking is banned, and appeal to young non-smokers to initiate smoking [16, 17]. With these concerns in mind, research is needed to establish the effects of repeated exposure to e-cigarette vapor. Moreover, although preliminary research suggests that e-cigarettes may be an effective tool for replacing regular cigarettes and for some, total cessation [40, 55], only a handful of studies exist and further research is needed to examine its role in smoking behavior. Furthermore, there are many different brands and types of e-cigarettes; there are also varying techniques of e-cigarette use. "Dripping" is one technique in which users of tank systems can apply the nicotine containing liquid directly to the coil that is heated which can cause inhalation of toxic chemicals (e.g., formaldehyde) at significantly higher levels than regular e-cigarettes [56]. It will be necessary to evaluate the varying risks among different e-cigarette products and techniques.

Less controversy exists regarding mHealth, however, it is important to consider the ethical considerations surrounding all mHealth interventions, including smoking cessation. Data collection and therapy through mobile phones creates the possibility of a breach in confidentiality. Future research is needed to examine the feasibility of mHealth programs in preventing unwanted access (e.g., cell phone carriers, hackers) to personal information. Furthermore, it is unlikely that each individual state will manage its own mHealth intervention, introducing the issue of practicing therapy across state lines. As mHealth develops, these issues will need to be addressed.

Conclusions

Tobacco interventions have been successful in reducing smoking among the population; however, the recent stagnation in the decline of smoking rates suggests that alternatives to traditional approaches are needed [7, 8]. The e-cigarette and mHealth interventions are two far-reaching alternative approaches that have both helped smokers quit or reduce their number of cigarettes smoked. However, these products, particularly the e-cigarette, have been subject to intense debate. Despite the controversies surrounding e-cigarettes and mHealth, current electronic aids appear to be realistic alternatives to help individuals quit smoking.

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Table 1

A sample of studies examining e-cigarettes during 2012–2013.

Citation	Methods	Conclusions	
Barbeau, Burda, & Siegel (2013)	Qualitative, FG; EC vs. NRT	• Perceptions: 1) ECs mimic real smoking, 2) social, 3) hobby, 4) identity, and 5) smoking vs. nicotine cessation.	• More social support for ECs than NRT • ECs seen as a cessation tool and safer than cigarettes.
Hua, Alfi, & Talbot (2013)	Qualitative, ECforums; EC Use	• Most common negative symptoms (81%): sneezing, burning mouth, blurred vision and bloody urine.	• Most common positive symptoms reported (19%): whiter teeth, improved overall health and lung functioning.
Hua, Yip, & Talbot (2013)	Qualitative, YouTube videos; EC vs. cigarettes	• EC users puff longer (m = 4.3s), but show larger variation (SD = 1.5s) than cigarette users (m = 2.4s, SD = 0.8s) • Puff duration varied significantly among EC brands.	• Gender and EC models do not moderate puff and exhalation duration. • More men than women EC users
Adkison et al. (2013)	Quantitative Survey, EC Awareness	• 46.6% aware, 7.6% tried, and 2.9% were current users. • Trying EC was higher among young, nondaily smokers, and high income individuals.	• Reasons to use EC: 79.8% considered less harmful than cigarettes; 75.4% to reduce smoking; and 85.1% to quit smoking.
Choi & Forster (2013)	Quantitative Survey, EC Awareness	• 69.9% aware, 7.0% tried, and 1.2% past 30 day use. • 26.3% agreed EC are less addictive than cigarettes	• 44.5% agreed EC can help people quit smoking • 52.8% agreed EC are less harmful than cigarettes
Dawkins, Turner, Roberts et al. (2013)	Quantitative Survey, EC brand Comparison	• 70% reported reduced urge to smoke; 72% used a ‘tank’ system. Ex-smokers report greater craving reduction than current smokers • EC considered satisfying; fewer side-effects; healthier than smoking; improve breathing.	• Ex-smokers’ ‘time to first vape’ was significantly longer than current smokers’ ‘time to first cigarette.’ • ECs used primarily for smoking cessation, but for a longer duration than NRT
King, Alam, Promoff et al. (2013)	Quantitative Survey, EC Awareness	• Awareness rose from 38.5% (mail survey) and 40.9% (web survey) to 57.9% from 2010–2011.	• Ever use of EC among current smokers (21.2%) was higher than former (7.4%) and never-smokers (1.3%). • Ever use of EC was 2.1% in the 2010 mail survey, 3.3% in the 2010 web survey, and 6.2% in the 2011 web survey.
Pepper et al. (2013)	Quantitative Survey, EC	• 67% of adolescent males had heard of ECs; Awareness higher among older and non-Hispanic adolescents.	• 18% willing to try EC, with more willingness among smokers and less willingness among NS with negative beliefs about typical smoker.
Goniewicz & Zielinska-Danch (2012)	Awareness Quantitative Survey, EC Use	• 23.5% of high school students had ever used EC and 8.2% had used in past 30 days.	• 19.0% of college students had ever used an EC and 5.9% had used in past 30 days.

Citation	Methods	Conclusions	
		• 3.2% of never smokers tried an EC.	• Most EC users previously tried cigarettes.
Pearson, Richardson, Niaura et al. (2012)	Quantitative Survey, EC Awareness	• 40.2% heard of ECs, awareness and use highest among current smokers.	• Non-Hispanic Whites, current smokers, young adults, and those with at least a high-school diploma most likely to perceive EC as less harmful than regular cigarettes.
Regan, Promoff, Dube et al. (2013)	Quantitative Survey, EC Awareness	• US awareness of EC doubled from 2009–2010 (16.4%–32.2%). • Ever use rose from 2009 (0.6%) to 2010 (2.7%).	• Current smokers and tobacco users most likely to try ECs. • Ever use of ECs was most common among women and those with lower education.
Seidenberg, Hong, Liu et al. (2012)	Quantitative Survey, Sale of Tobacco products	• Availability of tobacco products for sale: Cigarettes (100%), Cigars (69%), little cigars/cigarillos (66%), moist snuff (53%).	• Pipe tobacco (49%), roll-your-own tobacco (34%), snus (14%), dissolvable tobacco (11%) & ECs (2%).
Caponnetto, Auditore, Russo et al. (2013)	CLS; EC for NRT	• 64.3% participants reduced number of cig/day • 50% of participants reduced number of cig/day by at least 50%.	• Side effects reported: Nausea in 14.4%, throat irritation in 14.4%, headache in 14.4%, and dry cough in 28.6% of participants.
Caponetto et al. (2013)	RCT, EC	• Significant declines in cig/day and CO at each visit of 52 weeks for 7.2 mg, 5.4, and no- nicotine groups. • At least 50% reduction in 22.3% at 12 weeks and 10.3% at 52 weeks.	• 10.7% quit regular cigarettes at 12 weeks, and 8.7% at 52 weeks • 26.9% of quitters continued to use e-cigarettes at 52 weeks
Flouris et al. (2013)	CLS, EC smoking Vs. regular smoking	• EC and tobacco cigarettes generated similar serum cotinine levels after active and passive smoking.	• Active and passive EC smoking did not affect lung function, whereas active cigarette smoking did.
Dawkins, Turner, & Crowe (2012)	CLS, EC, Memory & NRT	• EC reduced desire to smoke and withdrawal symptoms (specifically anxiety), and improved time-based but not event-based prospective memory.	• The effect of nicotine was restricted to time-based is consistent with the view that nicotine acts to improve performance on strategic rather than automatic processing.
Flouris et al. (2012)	Chemistry Study, EC Smoking Vs. regular Smoking	• Active and passive EC smoking did not change complete blood count in smokers and NS.	• Active and passive increased white blood cell, lymphocyte, and granulocyte counts for at least 1 hr in smokers and never smokers.
Dawkins, Turner, Hasna et al. (2012)	CLS, EC & working memory (WM)	• Desire to smoke and nicotine withdrawal were significantly lower in the nicotine and placebo group.	• The nicotine EC improved WM performance compared with placebo at the longer interference intervals. • EC alleviated desire to smoke and withdrawal symptoms; nicotine content was more important for males.

Citation	Methods	Conclusions	
Goniewicz et al. (2013a)	CLS, EC vs. inhalator	• Levels of potentially toxic compounds are 9–450 times lower than regular cigarettes	• Some levels of potentially toxic chemicals are comparable to the inhalator
Goniewicz et al. (2013b)	CLS, EC	• ECs deliver less nicotine than regular cigarettes.	• EC models differ in efficacy and consistency of nicotine delivery.
Vansickel & Eissenberg (2012)	CLS, EC devices	• EC helped “feel awake,” “calm you down,” “concentrate,” was “pleasant” and “satisfying,” reduced hunger and “tasted good.”	• EC reduced anxiety, restlessness and intention to smoke. • Plasma nicotine and heart rate increased significantly within 5m and remained elevated during ad lib use period.
Vansickel, Weaver, & Eissenberg (2012)	CLS, EC vs. cigarettes	• EC increased heart rate and plasma nicotine levels, and decreased urge to smoke, anxiety, craving, impatience, irritability, and restlessness.	• Participants reported their own brand as being worth more ($) than ECs. • EC was rated as acceptable over time.
Vardavas et al. (2012)	CLS, EC & Pulmonary Function	• EC use lead to decrease in FeNO and increase in impedance, respiratory resistance and overall peripheral airway resistance.	

CLS = Clinical Laboratory Study; NRT = Nicotine Replacement Therapy; FG = Focus Groups; NS = nonsmokers; RCT = Randomized Control Trial

Table 2

A sample of mhealth studies over the last several years.

Citation	Methods	Conclusions	
Haug et al. (2009)	SMS	• Frequency of SMS texts per week did not affect smoking reduction, quit attempts, or self-efficacy.	• SMS-based smoking cessation interventions are attractive for young adults.
Abroms, Padmanabhan, Thaweetahi et al. (2011)	iPhone Apps	• No app strongly followed guidelines	
Free et al. (2011)	SMS	• Support delivered via text doubled quit rates at 6 months	
Whittaker et al. 2011	Video SMS	• 26.4% abstinence at 6 months vs. 27.6% in the control group.	• Video message do not enhance effects of SMS intervention.
Naughton, Prevost, Gilbert et al. (2012)	SMS	• MiQuit participants were more likely to set a quit date and reported higher self-efficacy, harm beliefs, and determination to quit.	
Whittaker et al. (2012)	Meta-Analysis	• mobile phone interventions increase long term quit rates	
Borland, Baimford, & Benda (2013)	RCT; SMS vs. Internet QuitCoach vs. Combined	• QuitCoach and/or interactive SMS showed no difference in 6-month sustained abstinence rate than a control group.	• Those who used an intervention had a significant overall increase in abstinence.
Devires, Kenward, & Free (2013)	SMS	• Younger, female smokers were more likely to relapse during the intervention • Sending a crave text, being female, younger, and setting a quit date on a Saturday were associated with shorter time to sending a first lapse text.	• Half of all crave texts arrived within 106 hours of quitting and half of all lapse texts arrived between 4 and 17 days after the quit date.
Naughton, Jamison, & Sutton (2013)	FG; SMS	• Text messaging was regarded as a highly convenient.	• Participants felt that the convenience of text messaging would increase interest in cessation content received compared to traditional formats.

Note. Short message service= SMS; Randomized Control Trial = RCT; Focus Groups = FG