AHA Scientific Statement

Current Science on Consumer Use of Mobile Health for Cardiovascular Disease Prevention

A Scientific Statement From the American Heart Association

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Although mortality for cardiovascular disease (CVD) has declined for several decades, heart disease and stroke continue to be the leading causes of death, disability, and high healthcare costs. Unhealthy behaviors related to CVD risk (eg, smoking, sedentary lifestyle, and unhealthful eating habits) remain highly prevalent. The high rates of overweight, obesity, and type 2 diabetes mellitus (T2DM); the persistent presence of uncontrolled hypertension; lipid levels not at target; and the ≈18% of adults who continue to smoke cigarettes pose formidable challenges for achieving improved cardiovascular health.[1,2] It is apparent that the performance of healthful behaviors related to the management of CVD risk factors has become an increasingly important facet of the prevention and management of CVD.[3]

In 2010, the American Heart Association (AHA) made a transformative shift in its strategic plan and added the concept of cardiovascular health.[2] To operationalize this concept, the AHA targeted 4 health behaviors in the 2020 Strategic Impact Goals: reduction in smoking and weight, healthful eating, and promotion of regular physical activity. Three health indicators also were included: glucose, blood pressure (BP), and cholesterol. On the basis of the AHA Life's Simple 7 metrics for improved cardiovascular health, <1% of adults in the United States follow a healthful eating plan, only 32% have a normal body mass index, and > 30% have not reached the target levels for lipids or BP. National Health and Nutrition Examination Survey (NHANES) data revealed that people who met ≥6 of the cardiovascular health metrics had a significantly better risk profile (hazard ratio for all-cause mortality, 0.49) compared with individuals who had achieved only 1 metric or none.[2] The studies reviewed in this statement targeted these behaviors (ie, smoking, physical activity, healthful eating, and maintaining a healthful weight) and cardiovascular health indicators (ie, blood glucose, lipids, BP, body mass index) as the primary outcomes in the clinical trials testing mobile health (mHealth) interventions.

eHealth, or digital health, is the use of emerging communication and information technologies, especially the Internet, to improve health and health care[4] (Table 1). mHealth, a subsegment of eHealth, is the use of mobile computing and communication technologies (eg, mobile phones, wearable sensors) for health services and information.[4,5] mHealth technology uses techniques and advanced concepts from an array of disciplines, for example, computer science, electrical and

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biomedical engineering, and medicine and health-related sciences.[16] Mobile devices that permit collection of data in real time are increasingly ubiquitous, enabling researchers to assess multiple behaviors in various contexts and thus inform the development of interventions to prompt behavior change. Technology-supported behavioral health interventions are designed to engage individuals in health behaviors that prevent or manage illness, and they have led to fundamental changes in health practices.[17] In addition to permitting more frequent and convenient community-based assessment of health parameters, these technology-mediated tools support the exchange of health information among consumers and between consumers and health providers, enable health decision making, and encourage positive health behaviors, including self-management and health promotion.[18,19] Consequently, mHealth technologies are becoming more prevalent, and their use will continue to grow,[20] consistent with the Institute of Medicine's call to increase the design and testing of health technologies.[21]

The ubiquity of mobile devices presents the opportunity to improve health outcomes through the delivery of state-of-the-art medical and health services with information and communication technologies.[22] Because of their diverse capabilities and advanced computing features, smartphones are often considered pocket computers.[16] In addition to these devices that can inform and communicate, there are wearable sensors that can be worn for short or extended periods and monitor activity or physiological changes (eg, exercise, heart rate, sleep). These sensors can provide data in real time or save the data to a device for later uploading and review.

The US Food and Drug Administration has a public health responsibility to oversee the safety and effectiveness of medical devices. However, this applies only to applications (apps) that are accessory to regulated medical devices (eg, apps that diagnose a condition). Many mobile apps are not medical devices, meaning that they do not meet the definition of a device under section 201(h) of the Federal Food, Drug, and Cosmetic Act, and the US Food and Drug Administration does not regulate them. Some mobile apps may meet the definition of a medical device, but because they pose a lower risk to the public, the US Food and Drug Administration intends to exercise enforcement discretion over these devices. Most of the mHealth apps on the market at this time fit into these 2 categories.[23,24]

Numerous innovations in health information technology are empowering individuals to assume a more active role in monitoring and managing their chronic conditions and therapeutic regimens, as well as their health and wellness.[25] These advances are increasingly accepted by the public.[26] Unlike the initial digital divide that placed computer use and Internet access beyond the reach of many older, disabled, and low-income individuals, mobile devices have been widely adopted across demographic and ethnic groups, especially those most in need of health behavior interventions.[27,28] This trend is confirmed in the 2014 statistics from the Pew Research Center's Internet and American Life Project, which showed that 81% of households with an income above $75 000/y owned a smartphone, and nearly half (47%) of those with an annual household income below $30 000 owned a smartphone.[29]

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Table 1. Glossary of Commonly Used mHealth Terms

eHealth	eHealth, or digital health, is the use of emerging communication and information technologies, especially the use of the Internet, to improve health and health care.[4]
mHealth	A subsegment of eHealth, mHealth is the use of mobile computing and communication technologies (eg, mobile phones, wearable sensors) for health services and information.[4,5]
SMS	SMS is a text messaging service component of mobile devices. It uses standardized communications protocols to allow mobile phone devices to exchange short text messages. The terms text messaging and texting are used interchangeably to refer to both the medium and messages, and the term text message refers to the individual message sent.[6]
MMS	MMS is the next evolutionary step from SMS. MMS allows mobile phone users to exchange pictures with sound clips on their handsets or digital cameras.[7]
App	App is short for application, which is the same thing as a software program. Although an app may refer to a program for any hardware platform, it is most often used to describe programs for mobile devices such as smartphones and tablets.[8]
Wireless	Being wireless means not using wires to send and receive electronic signals (ie, sending and receiving electronic signals by using radio waves).[9]
Wi-Fi	Wi-Fi is a wireless networking technology that allows computers and other devices to communicate over a wireless signal.[10]
Bluetooth	This wireless technology enables communication between Bluetooth-compatible devices. It is used for short-range connections between desktop and laptop computers, a mouse, digital cameras, scanners, cellular phones, and printers.[11]
Operating system	An operating system, or OS, is software that communicates with the hardware and allows other programs to run. Common mobile OSs include Android, iOS, and Windows Phone.[12]
iOS	iOS is a mobile OS developed by Apple. It was originally called the iPhone OS, but was renamed to the iOS in June 2009. The iOS currently runs on the iPhone, iPod Touch, and iPad.[13]
Android OS	Android OS is a Linux-based open-source platform for mobile cellular handsets developed by Google and the Open Handset Alliance. Android 1.0 was released in September 2008.[14]
Bandwidth	In computer networks, bandwidth is used as a synonym for data transfer rate, the amount of data that can be transmitted from one point to another in a given time period (usually a second). Network bandwidth is usually expressed in bits per second (bps); modern networks typically have speeds measured in the millions of bits per second (megabits per second or Mbps) or billions of bits per second (gigabits per second or Gbps).[15]

MMS indicates multimedia messaging service; OS, operating system; and SMS, short messaging service.

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The highest smartphone ownership was among Hispanic and blacks, at 61% and 59%, respectively. Of those with phones who use the Internet, 34% mostly use their phones, rather than a desktop or laptop, to access online programs.[30]

Mobile devices offer great promise for improving the health of the populace. Most smartphones include basic functionalities, for example, video streaming, e-mail, Internet access, and high-quality imaging. These developments in wireless technology and the shift to mobile devices are demanding a re-examination of technology as it currently exists within the healthcare infrastructure.[16] However, the pace of science in evaluating these apps is incongruent with the business and industry sectors and the consumer demands. There are concerns that the health-promoting smartphone apps being developed fail to incorporate evidence-based content and that rigorous testing to provide efficacy data is trailing behind their adoption.[31–34] However, a systematic review of the literature suggests a positive impact of consumer health informatics tools on select health conditions. For example, there were intermediate outcomes such as knowledge, adherence, self-management, and change in behaviors related to healthful eating, exercise, and physical activity but not obesity.[35] Another review suggests that smartphone apps are useful tools at the point of care and in mobile clinical communication, as well as in remote patient monitoring and self-management of disease.[36]

Recent articles have reviewed the latest technological advances in digital social networks related to health[37] and wireless devices for cardiac monitoring.[38] What is missing in the scientific literature is a report on the health-related mobile technologies focused specifically on CVD prevention. In particular, it is important to investigate the degree to which these CVD-focused technologies include best content and have been evaluated for their effectiveness. In the absence of such data, clinicians may be hesitant to recommend or endorse any program to their patients and thereby potentially miss an opportunity to improve their engagement in healthful behaviors.

The aims of this scientific statement are to review the literature on mHealth tools available to the consumer in the prevention of CVD (eg, dietary self-monitoring apps, physical activity monitors, and BP monitors); to provide the current evidence on the use of the vast array of mobile devices such as use of mobile phones for communication and feedback, smartphone apps, wearable sensors, or physiological monitors that are readily available and promoted to the public for monitoring their health; and to provide recommendations for future research directions. The goal is to provide the clinician and researcher a review of the current evidence on using mHealth tools and devices when targeting behavior change, cardiovascular risk reduction, and improved cardiovascular health. This statement is divided into sections by the behaviors or health indicators included in the AHA's Life's Simple 7 program: achieving a healthful weight, improving physical activity, quitting smoking, achieving blood glucose control, and managing BP and lipids to achieve target levels. Within each section, the recent evidence for studies using mHealth approaches is reviewed, gaps are identified, and directions for future research are provided.

Although the majority of studies reported the use of mobile devices, for example, basic mobile phones that support the use of text messaging (short message service [SMS]) or smartphones that provide Internet access, several reported interventions delivered via the Internet such as studies reporting on increased physical activity or BP management. The writing group made the decision to include these studies because there is an increasingly greater proportion of people accessing the Internet via mobile devices. As noted in a Pew report in February 2014, 68% of adults access the Internet with mobile devices.[39] This figure has likely increased in the past year. Moreover, in some of the designated areas of cardiovascular risk, there were few studies reporting on the use of mHealth supported interventions.

Review of the Scientific Literature on mHealth Tools Related to CVD Prevention

Search Strategy

We conducted a literature search that included the following terms: *mHealth*; *mobile health*; *mobile phone*; *mobile device*; mobile technology; *mobile communication*; *mobile computer*; *mobile PC*; *cell phone*; *cellular phone*; *cellular telephone*; *handheld computer*; *handheld device*; *handheld technology*; *handheld PC*; *hand held computer*; *hand held device*; *hand held technology*; *hand held PC*; *tablet device*; *tablet computer*; *tablet technology*; *tablet PC*; *smartphone*; *smart phone*; *iPad*; *Kindle*; *Galaxy*; *iPhone*; *Blackberry*; *iPod*; *Bluetooth*; *short message service*; *SMS*; *pocket PC*; *pocketPC*; *PDA*; *personal digital assistant*; *Palm Pilot*; *Palmpilot*; *smartbook*; *mobile telephone*; *messaging service*; *MP3 player*; *pormedia player*; *podcast*; *email*; *e-mail*; *electronic mail*; and *electronic message*. Search terms used within the technology or clinical topic (eg, diabetes mellitus) groups were divided with "or," and the search terms between the technology and clinical topic were connected with "and." Within each subsection, the key terms used in the search for a given clinical topic are identified. The search was limited to the past 10 years (2004–2014) and to studies reported in the English language. We limited our review to studies enrolling adults except for smoking cessation, for which we included adolescents. We included studies conducted in the United States and in developed countries. We also briefly discuss key systematic reviews or meta-analyses in each topic area, except in management of dyslipidemia.

Use of mHealth to Improve Weight Management

Obesity causes or contributes to myriad physical and mental health conditions such as CVD, T2DM, and depression, which, either individually or collectively, represent the leading causes of morbidity and mortality in the United States.[40–42] More than 35% of US adults >20 years are obese,[43] and >1 in 4 Americans have multimorbidity,[45] which is associated with high healthcare use and costs, functional impairment, poor quality of life, psychological distress, and premature death.[46–50] Sustained weight loss of 3% to 5% can delay or possibly prevent T2DM[51,52] and significantly improve CVD risk factors (eg, abnormal glucose, elevated BP).[53–56] However, effective treatments for obesity that are accessible to consumers, affordable for diverse socioeconomic groups, and scalable at a population level are lacking.

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The 2013 obesity treatment guideline by the AHA, the American College of Cardiology (ACC), and The Obesity Society recommended that clinicians advise overweight and obese individuals who would benefit from weight loss to participate for ≥6 months in a comprehensive lifestyle program characterized by a combination of a reduced calorie intake, increased physical activity, and behavioral strategies.[57] The guideline panelists found evidence of moderate strength supporting the efficacy of electronically delivered, comprehensive lifestyle programs that include personalized feedback from a trained interventionist, defined as programs delivered to participants by the Internet, e-mail, mobile texting, or similar electronic means. Therefore, it was recommended that electronically delivered interventions are an acceptable alternative to in-person interventions, although it was recognized that the former may result in smaller weight loss than the latter.

Use of mHealth in Weight Management Interventions

This review is limited to technology-supported lifestyle behavioral interventions for weight loss. Readers are referred to numerous systematic reviews of more traditional Internet-, e-mail–, and telephone-based lifestyle interventions for weight loss.[58–63] Overall, weight management interventions have used a range of mobile technologies,[60,64–68] including texting (SMS), smartphone applications, handheld personal digital assistants (PDAs), and interactive voice response (IVR) systems.[66,69,70] Numerous network-connected devices have also been used,[60,64] including e-scales and wireless physical activity monitoring devices.[71] The use of mobile devices and their functionality (eg, SMS and multimedia messaging service, mobile Internet, and software apps) in weight loss interventions have improved exponentially in recent years. In this section, we focus on the latest evidence on mobile technology interventions for weight loss.

With few exceptions,[72] most interventions have used a single, predetermined technology and did not give participants the option of choosing between a single or multiple forms of technology simultaneously (which has become commonplace for commercial applications). Most technologies have been created in research settings, although at least 1 published study used a commercially available app.[71] The majority of these trials were focused primarily on efficacy testing, and it was unclear whether these interventions used strategies designed to promote user engagement (eg, using established design principles, conducting usability testing, or undergoing iterative development and testing). Additionally, a key translational challenge is that many commercial apps have not been tested empirically, and many apps with empirical data are not commercially available.

Review of Evidence for the Efficacy of mHealth-Based Weight Loss Interventions

We conducted an electronic literature search using Medline (PubMed), CINAHL, and PsychInfo in June 2014 and extended to 2004. Search terms for this topic included the following: *overweight*, *obese*, *obesity*, *body mass*, *adiposity*, *adipose*, *weight loss*, and *weight gain*. Only original studies with human subjects with a primary outcome of weight loss and published in English were included. Of 184 references identified, 169 were excluded on the basis of a review of the title (n=19), abstract (n=121), and full text (n=29). Fourteen references were eligible for this review, including 10 studies conducted among US adults and 2 among adults outside the United States.

Table 2 includes the studies reviewed and provides details on study design, intervention, sample characteristics, and primary outcomes. Five of the 8 US randomized, controlled trials (RCTs)[74–76,83,84] reported significantly more weight loss in the intervention group than in the control or comparison group. The testing and use of mobile technologies varied a great deal, and combinations of mHealth components and tools were often very specific to a particular study. Five investigators used text messaging, also referred to as SMS,[73,74,79,82,83] in studies that ranged from 8 weeks to 1 year in duration. Patrick et al[74] permitted the participant to set the frequency of the SMS (2–5 times a day) and found a significant difference in weight loss between the 2 groups at 4 months, whereas Napolitano et al[83] observed better weight loss in the Facebook plus SMS than the Facebook alone group at 8 weeks. Only 1 study,[79] which used SMS and multimedia messaging service 4 times a day in addition to a monthly e-newsletter in a 12-month study, did not observe a significant difference in weight loss compared with a monthly e-newsletter control group. Two of the SMS studies were conducted outside the United States. Carter et al[82] observed greater weight loss at 6 months in the group receiving SMS compared with the Web site plus Internet forum or paper diary plus Internet forum groups, whereas Haapala et al[73] demonstrated similar results in a study that compared SMS with a wait-list control group at 12 months. Although none of the US studies using SMS reported positive findings beyond 9 months, the Finnish study[73] showed that an SMS intervention could result in significantly greater weight loss than no intervention for up to 12 months.

Shuger et al[76] reported a study that tested the Bodymedia armband for monitoring daily physical activity with a wristwatch display with or without a behavioral intervention and compared it with 2 groups not using the armband. Only the armband plus intervention group achieved significantly greater weight loss than the self-directed control group at 9 months. Two investigators[77,84] used PDAs for self-monitoring. Burke et al[77] compared 3 standard behavioral weight loss interventions that differed in the method of self-monitoring by using a paper diary or a PDA with or without daily tailored feedback messages via the PDA and found no difference in weight loss at 2 years. Spring et al[84] compared a biweekly group weight loss intervention with the same intervention plus PDA-based self-monitoring and personalized coach feedback by phone. They observed significantly different weight loss at 6 months, but the effect was not sustained at 12 months.

Turner-McGrievy et al[75] reported that a theory-based podcast delivered via MP3 players or computers led to significantly greater weight loss than a non–theory-based weight loss podcast at 12 weeks. Building on this study, the investigators[80,81] conducted a follow-up study to compare the incremental effect of adding mobile apps for self-monitoring and communication with a health coach and group members to the theory-based podcast. However, the addition did not result in significantly greater weight loss than the podcast alone at 6 months.[80,81]

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Table 2. Description of Studies Using mHealth for Weight Loss or Weight Maintenance

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
Haapala et al,[73] 2009 Design: 2-group RCT Outcome: wtΔ and waist circumference Δ Setting: Community Country: Finland	N=125 Int1: n=62 Int2: n=63 Women: 77.4% Mean age (SD): Int1: 38.1 (4.7) y Int2: 38.0 (4.7) y BMI: Int1: 30.6 (2.7) kg/m^2 Int2: 30.4 (2.8) kg/m^2 Retention: Int1: 73% Int2: 65%	Int1: SMS (for personalized feedback) and study Web site (for tracking and information) Diet: Cut down on unnecessary food intake and alcohol PA: Increase daily physical activity Behavior: Self-monitoring and reporting of wt via SMS or study Web site Int2: Wait list control No Intervention	Mobile phone, SMS, study Web site	Duration: 1 y Contacts: Int1: Real time when participants reported wt via text messaging Int2: No intervention contact Intervention adherence: Mean No. (SD) of Ps reporting wt via SMS or study Web site per week: 3 mo: Int1: 8.2 (4.0) 6 mo: Int1: 5.7 (4.6) 9 mo: Int1: 3.7 (3.5) 12 mo: Int1: 3.1 (3.5) Interventionist: Int1: Automated Int2: NA	ITT (LOCF) 12 mo: wtΔ, kg, M (SD): Int1: −3.1 (4.9) Int2: −0.7 (4.7) *P*=0.008 Waist circumference Δ, cm, M (SD): Int1: −4.5 (5.3) Int2: −1.6 (4.5) *P*=0.002
Patrick et al,[74] 2009 Design: 2-group RCT Outcome: wtΔ Setting: Community Country: United States	N=78 Int1: n=39 Int2: n=39 Mean age (SD): 44.9 (7.7) y Women: 80% White: 75% Black: 17% BMI: Int1: 32.8 (4.3) kg/m^2 Int2: 33.5 (4.5) kg/m^2 Retention: Int1: 67% Int2: 67%	Int1: Mobile phone wt loss program Diet goal: 500-kcal/d reduction PA: Increase from baseline Behavior: Self-monitoring weekly wt using mobile phone; time/frequency of tailored SMS set by Ps (2–5 times/d), monthly phone calls by coach Int2: Mail Diet: No intervention PA: No intervention Behavior: Monthly mailings (healthful eating, PA, and wt loss)	Mobile phone SMS and MMS	Duration: 4 mo Contacts: Int1: Daily SMS and MMS, frequency set by Ps Int2: 4 monthly mailings Intervention adherence: Int1: 100% adherence to responding to all messages requesting a reply; by week 16, ≈66%. Int2: NR Interventionist: Int1: Health coach+automated Int2: NA	LOCF imputation 4 mo: wtΔ, kg, M (SE): Int1: −2.10 (0.51) Int2: −0.40 (0.51) *P*=0.03 Completers only: Int1: −2.46 (0.64) Int2: −0.47 (0.64) *P*=0.04
Turner-McGrievy et al,[75] 2009 Design: 2-group RCT Outcome: wtΔ Setting: Community Country: United States	N=78 Int1: n=41 Int2: n=37 Mean age (SD): Int1: 37.7 (11.8) y Int2: 39.6 (12.2) y Women: Int1: 68% Int2: 81% White: Int1: 85% Int2: 78% BMI: Int1: 31.8 (3.2) kg/m^2 Int2: 31.4 (4.1) kg/m^2 Retention: Int1: 90% Int2: 92%	Int1: Social cognitive theory–based wt loss podcast Diet: Increase fruit and vegetable intake, decrease fat intake PA: Increase from baseline Behavior: Encourage tracking wt, calories, and exercise Int2: Non–theory-based wt loss podcast Diet: Avoid overeating PA: NR Behavior: NR	Podcast via MP3 player or computer for Int1 and Int2	Duration: 12 wk Contacts: Int1: 2 podcasts/wk (mean length, 15 min) Int2: Same as Int1 (mean length, 18 min) Intervention adherence: Mean (SD) No. of podcasts listened to (n =24): Int1: 17.5 (8.1) Int2: 16.6 (7.5) *P*<0.67 Interventionist: Int1: Automated Int2: Automated	ITT (BOCF) 12 wk: wtΔ, kg, M (SD): Int1: −2.9 (3.5) Int2: −0.3 (2.1) *P*<0.001 BMI Δ, kg/m^2, M (SD): Int1: −1.0 (1.2) Int2: −0.1 (0.7) *P*<0.001

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Table 2. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
Shuger et al,[76] 2011 Design: 3-group RCT Outcome: wt Setting: Community Country: United States	N=197 Int1: n=49 Int2: n=49 Int3: n=49 Int4: n=50 Mean age (SD): 46.9 (10.8) y Women: 81.7% White: 66.8% Black: 32.1% BMI: Int1: 33.0 (5.0) kg/m^2 Int2: 33.2 (5.4) kg/m^2 Int3: 33.1 (4.8) kg/m^2 Int4: 33.7 (5.5) kg/m^2 Retention: At 4 mo: 70% At 9 mo: 62%	Int1: Group-based behavioral wt loss program+armband Diet: adopt healthful eating pattern PA: Increase PA+armband Behavior: Self-monitoring of daily meal, lifestyle activity, and emotion/mood+weekly weigh-in and coach-directed sessions for wt loss support and maintenance Int2: Armband alone Diet: adopt healthful eating pattern PA: Increase PA+armband Behavior: self-monitoring of daily meal, lifestyle activity, and emotion/mood+real-time feedback on energy expenditure, minutes spent in moderate and vigorous PA, and steps/d Int3: Group-based behavioral wt loss program alone Diet: Same as Int1+emphasis on wt loss PA: Same as Int1 Behavior: Same as Int 1+weekly weigh-in and coach-directed sessions for wt loss support and maintenance Int4: Self-directed wt loss program following an evidence-based manual Diet: Adopt healthful eating pattern PA: Increase PA Behavior: Self-monitoring of daily meal, lifestyle activity, and emotion/mood	Bodymedia armband with a real-time wrist watch display and a personalized wt management solutions Web account	Duration: 9 mo Contacts: Int1: Same as Int2 and Int3 Int2: Real time when participants uploaded armband and recorded daily energy intake and body wt to the Web site Int3: 14 weekly group sessions during the first 4 mo; 6 1-on-1 phone counseling sessions during the final 5 mo Int4: 1 Self-directed wt loss manual Intervention adherence: NR Interventionist: Int1: Health coach+automated Int2: Automated Int3: Health coach Int4: NA	ITT (how handled missing data NR) Baseline: Wt, kg, M (SE): Int1: 100.32 (2.97) Int2: 101.15 (2.95) Int3: 101.84 (2.95) Int4: 102.22 (2.97) NSD among 4 groups 4 mo: Wt, kg, M (SE): Int1: 96.83 (2.99) Int2: 98.48 (2.97) Int3: 100.74 (2.99) Int4: 101.23 (3.03) *P*=NR 9 mo: Wt, kg, M (SE): Int1: 93.73 (2.99) Int2: 97.60 (2.99) Int3: 99.98 (3.00) Int4: 101.32 (3.05) Int1 vs Int4: *P* =0.04 Int2 or Int3 vs Int4: *P*=NR
Burke et al,[77] 2012; Burke et al,[78] 2011 Design: 3-group RCT Outcome: % wtΔ at 6 and 24 mo Setting: Community/ academic center Country: United States	N=210 Int1: n=68 Int2: n=70 Int3: n=72 Mean age (SD): 46.8 (9.0) y Women: 84.8% White: 78.1% Median BMI (IQR): 33.09 (6.89) kg/m^2	Int1: PDA only Diet: 1200–1800/d calorie goal based on wt and sex; ≤25% of total calories from fat PA: Increase by 30 min semiannually to 180 min by 6 mo Behavior: Self-monitoring with PDA	PDA with dietary and PA self-monitoring program, daily remotely delivered feedback message in real time to Int2 group	Duration: 24 mo Contacts: Int1: Weekly group sessions for months 1–4, biweekly for months 5–12, and monthly for months 13–18, 1 session during the last 6 mo Int2: Same as Int1 Int3: Same as Int1	ITT (0.3 kg/mo was added to previous observation) 6 mo: % wtΔ, %, M (SD): Int1: −4.88% (6.20) Int2: −6.58% (6.77) Int3: −4.59% (5.66) NSD 24 mo: % wtΔ, %, M (SD): Int1: −1.18% (8.78) Int2: −2.17% (7.04) Int3: −1.77% (7.23) NSD

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Table 2. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
	Retention: Int1: 86.8% Int2: 84.3% Int3: 86.1%	Int2: PDA with daily tailored feedback message Diet: Same as Int1 PA: Same as Int1 Behavior: Self-monitoring with PDA and receiving automated daily feedback on calories or fat intake. Int3: Paper diary Diet: Same as Int1 PA: Same as Int1 Behavior: Self-monitoring with paper diary and a nutritional reference book		Intervention adherence: ≥30% adherent to dietary self-monitoring at 18 mo Int1: 19%–20% Int2: 19%–20% Int3: 8% Interventionist: Int1: Dietitians and exercise physiologists Int2: Dietitians and exercise physiologists+automated Int3: Dietitians and exercise physiologists	
Shapiro et al,[79] 2012 Design: 2-group RCT Outcome: % wtΔ Setting: Community Country: United States	N=170 Int1: n=81 Int2: n=89 Mean age (SD): 41.9 (11.8) y Women: 65% White: 64% BMI: Int1: 32.4 (4.2) kg/m^2 Int2: 32.0 (4.0) kg/m^2 Retention: Int1: 79% Int2: 89%	Int1: e-newsletter+SMS and MMS+Web site Diet: 500 kcal/d reduction goal PA goal: 12 000 steps/d with a gradual increase of 750 steps/wk, then encourage increase PA time or walk at a faster pace Behavior: Self-monitoring daily step count and weekly wt, automated personalized feedback on progress via mobile phone, accessing health tips, recipes, food and PA logs, wt chart on a Web site Int2: e-newsletter control Diet: Same as Int1 from e-newsletters only PA: Same as Int1 from e-newsletters only Behavior: No intervention	Mobile phone SMS and MMS	Duration: 12 mo Contacts: Int1: SMS and MMS 4 times/d, monthly e-newsletters Int2: Monthly e-newsletters Intervention adherence: Responses to SMS. Int1: knowledge testing questions: 60%, the first pedometer steps questions: 51%, and the first wt questions: 55% Int2: NA Interventionist: Int1: Automated Int2: NA	Imputation via MICE At 6 mo (primary): wtΔ, lb, M (SE): Int1: −3.72 lb (9.37) Int2: −1.53 lb (7.66) *P*=0.110 12 mo (secondary): wtΔ, lb, M (SE): Int1: −3.64 lb (12.01) Int2: −2.27 lb (9.39) *P*=0.246
Turner-McGrievy and Tate,[80] 2011, Turner-McGrievy et al,[81] 2013 Design: 2-group RCT Outcome: wtΔ Setting: Community Country: United States	N=96 Int1: n=47 Int2: n=49 Mean age (SD): Int1: 42.6 (10.7) y Int2: 43.2 (11.7) y Women: Int1: 77% Int2: 73% White: Int1: 75% Int2: 78% BMI: Int1: 32.9 (4.8) kg/m^2 Int2: 32.2 (4.5) kg/m^2 Retention: Int1: 89% Int2: 90%	Int1: Podcast+mobile group Diet: Reduction of ≥500 kcal/d, decrease dietary fat to <30% of total energy, limit added sugar, increase fruit and vegetable consumption PA: Goal minimum of 30 min/d of moderate to vigorous PA by week 4 Behavior: Same as Int2+self-monitoring diet, PA using mobile app, social support group members via Tweets app	App on mobile phone	Duration: 6 mo Contacts: Int1: Same as Int2+daily contacts with coaches and group members via mobile app Int2: 2 15-min podcasts/wk for 3 mo, 2 mini-podcasts/wk for 3 mo Intervention adherence: Podcasts (n=24) downloaded, %: 0–3 mo: Int1:68% Int2: 60.4% 4–6 mo: Int1: 37.5% Int2: 34.1%	ITT (BOCF) 3 mo: % wtΔ, %, M (SD): Int1: −2.6% (3.5) Int2: −2.6 % (3.8) NSD 6 mo (primary): % wtΔ, %, M (SD): Int1: −2.7% (5.6) Int2: −2.7% (5.1) NSD

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Table 2. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
		Int2: Podcast group Diet: Same as Int1 PA: Same as Int1 Behavior: overcoming barriers and problem solving, self-monitoring diet using book with calorie and fat gram content		% Adherence to self-monitoring diet: 0–3 and 4–6 mo: Int1: 41.4% and 24.3% Int2: 34.3% and 18.6% Percent adherence to recording PA: 0–3 and 4–6 mo: Int1: 34.3% and 21.4% Int2: 37.1% and 22.8% Interventionist type: Int1: Study coordinator Int2: NA	
Carter et al,[82] 2013 Design: 3-group RCT Secondary outcome: wtΔ, BMIΔ, %body fatΔ Setting: Community Country: United Kingdom	N=128 Int1: n=43 Int2: n=42 Int3: n=43 Mean age (SD): Int1: 41.2 (8.5) y Int2: 41.9 (10.6) y Int3: 42.5 (8.3) y Women: 77.3% White: Int1: 100% Int2: 92.9% Int3: 83.3% BMI: Int1: 33.7 (4.2) kg/m^2 Int2: 34.5 (5.6) kg/m^2 Int3: 34.5 (5.7) kg/m^2 Retention: Int1: 93% Int2: 55% Int3: 53%	Int1: Apps on mobile phone+SMS+Internet forum (for social support) Diet: NR PA: NR Behavior: Wt loss goal setting, self-monitoring daily calorie intake, PA, and wt, instant or weekly feedback via SMSs to enhance self-efficacy and reinforce positive behaviors Int2: Web site+Internet forum (for social support) Diet: NR PA: NR Behavior: Goal setting and self-monitoring Int3: Paper diary+Internet forum (for social support) Diet: NR PA: NR Behavior: Goal setting and self-monitoring	App on mobile phone, SMS	Duration: 6 mo Contacts: Int1: Instant and weekly Int2: No intervention contact Int3: No intervention contact Intervention adherence: Mean days of dietary self-monitoring: Int1: 92 (67) Int2: 35 (44) Int3: 29 (39) P<0.001 Interventionist type: Int1: Automated Int2: NA Int3: NA	ITT (BOCF) 6 mo (not powered to detect significance): wtΔ, kg, M (95% CI): Int1: −4.6 (−6.2 to −3.0) Int2: −1.3 (−2.7 to 0.1) Int3: −2.9 (−4.7 to −1.1) Int1 vs Int2: P<0.05; Int1 vs Int3: P=0.12 BMI Δ, kg/m^2, M (95% CI): Int1: −1.6 (−2.2 to −1.1) Int2: −0.5 (−0.9 to 0.0) Int3: −1.0 (−1.6 to −0.4) P=NR % Body fat Δ, %, M (95% CI): Int1: −1.3 (−1.7 to −0.8) Int2: −0.5 (0.9 to 0.0) Int3: −0.9 (−1.5 to −0.4) P=NR
Napolitano et al,[83] 2013 Design: 3-group RCT Outcome: wtΔ Setting: Academic setting Country: United States	N=52 Int1: n=17 Int2: n=18 Int3: n=17 Mean age (SD): 20.5 (2.2) y Women: 86.5% White: 57.7% Black: 30.8% Hispanic: 5.8% Asian: 1.9% BMI: 31.36 (5.3) kg/m^2	Int1: Facebook Diet: Calorie target based on wt PA: Target ≥ 250 min of mod intensity exercise per week Behavior: Self-monitoring, planning, stress management, social support, special occasion tips, relapse prevention	Mobile phone, SMS, social media	Duration: 8 wk Contacts: Int1: 8 weekly Facebook sessions Int2: Same as Int1, daily SMSs Intervention adherence: Responses to SMS Int1: NA Int2: Self-monitoring SMS 68.5%, general monitoring SMS 79.8% Int3: NA	ITT (ways to deal with missing data NR) 4 wk: wtΔ, kg, M (SD): Int1: −0.46 kg (1.4) Int2: −1.7 kg (1.6) Int3: 0.28 kg (1.7) P≤0.01 Post hoc contrasts showed Int2 was significantly different from Int1 (P<0.05) and Int3 (P≤0.001)

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Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
	Retention: Int1: 100% Int2: 89% Int3: 100%	Int2: Facebook+SMS and personalized feedback Diet: Same as Int1 PA: Same as Int1 Behavior: Same as Int1, sent self-monitoring data via SMS, received daily SMS on self-monitoring of calorie, PA, and wt goals, received weekly summary reports via Facebook link, and selected a buddy for support Int3: Wait list control No intervention		Interventionist type: Int1: NA Int2: Automated Int3: NA	8 wk (primary): wtΔ, kg, M (SD): Int1: −0.63 kg (2.4) Int2: −2.4 kg (2.5) Int3: −0.24 kg (2.6) P<0.05 Post hoc contrasts showed Int2 was significantly different from Int1 (P<0.05) and Int3 (P<0.05)
Spring et al,[84] 2013 Design: 2-group RCT Outcome: wtΔ Setting: Veterans Affairs medical center Country: United States	N=70 Int1: n=35 Int2: n=35 Mean age (SD): 57.7 (11.9) y Women: 14.5% White: 69.6% Minorities: 30.4% BMI: Int1: 36.9 (5.4) kg/m^2 Int2: 35.8 (3.8) kg/m^2 Retention: Int1: 83% Int2: 80%	Int1: Standard+connective mobile technology system Diet: Same as Int2, calorie reduction was wt loss based. PA: Same as Int2, goal=60 min/d of mod-intensity PA with 25% increase if previous goal met Behavior: Wt loss phase (1–6 mo): Same as Int2, self-monitoring and regulating food intake and PA using PDA daily first 2 wk, then weekly until 6 mo, personalized feedback from coach every 2 wk via 10–15 min phone call; Maintenance phase (7–12 mo): Same as Int2, recorded and transmitted data biweekly during 7–9 mo and 1 wk/mo during 10–12 mo Int2: Standard of care Diet: 18 MOVE! group sessions PA: 18 MOVE! sessions Behavior: Wt loss phase (1–6 mo): 12 bi-weekly MOVE! sessions, self-monitoring encouraged; Maintenance phase (7–12 mo): 6 monthly MOVE! support group sessions	PDA	Duration: 12 mo Contacts: Int1: Biweekly group sessions in months 1–6, monthly sessions in months 7–12 Int2: Same as Int1 Intervention adherence: Mean number of MOVE! sessions attended Int1: 6.2 (34%) of 18 sessions Int2: 5.9 P=0.54 Mean (SD) number of treatment calls received by Int1: 8.9 (2.8) Interventionist type: Int1: Dietitians, psychologists, or physicians Int2: Dietitians, psychologists, or physicians+ paraprofessional coach	ITT, ways to deal with missing data NR 3 mo: wtΔ, kg, M (95% CI): Int1: −4.4 kg (−2.7 to −6.1) Int2: −0.86 kg (−0.04 to −1.8) P<0.05 6 mo: wtΔ, kg, M (95% CI): Int1: −4.5 kg (−2.1 to −6.8) Int2: −1.0 kg (0.7 to −2.5) P<.05 9 mo: wtΔ, kg, M (95% CI): Int1: −3.9 kg (−0.8 to −6.9) Int2: −0.9 kg (1.1 to −2.9) P<.05 12 mo: wtΔ, kg, M (95% CI): Int1: −2.9 kg (−0.5 to −6.2) Int2: −0.02 kg (2.1 to −2.1) NS

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Table 2. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean Weight Loss (kg, kg/m^2, or % Change)
Systematic review and meta-analysis					
Siopis et al,[66] 2014 Design: Meta-analysis of 6 RCTs Outcome: Mean wtΔ Setting: NR	N ranged from 51–927 Retention: 47%–96%	Int1: SMS Int2: Group session diet/exercise intervention or no intervention	Mobile phone, SMS	Duration: 8 wk–12 mo Intervention adherence: NR	Pooled wtΔ, kg, M (95%CI) Int1: −2.56 (−3.46 to −1.65) Int2: −0.37 (−1.22 to −0.48) Meta-regression results: Int mean wt Δ 2.17 kg higher than Int2 group (95% CI, −3.41 to −0.93; *P*=0.001)

Automated indicates without a clinician who generates, tailors, or modifies the output; BMI, body mass index; BOCF, baseline observation carried forward; CI, confidence interval; Δ, change or difference; Int, intervention group; IQR, interquartile range; ITT, intention to treat; LOCF, last observation carried forward; M, mean; MICE, multivariate imputation by chained equations; MMS, multimedia messaging service; n, subgroups; N, total sample; NA, not applicable; NR, not reported; NS, not significant; NSD, not significantly different; P, participant; PA, physical activity; PDA, personal digital assistant; RCT, randomized control trial; SMS, short message service; and wt, weight.

Two adult RCTs were conducted outside the United States (Table 2). The 6-month UK study[82] compared a self-directed smartphone app for goal setting and self-monitoring plus automated tailored feedback via text messaging with a Web site control and a paper diary control. Compared with the 2 other groups, the smartphone group achieved significantly greater mean weight loss at 6 months. The 1-year Finnish study[73] was the only mobile technology intervention reviewed in the 2013 AHA/ACC/TOS obesity treatment guideline. It tested a weight loss intervention via text messaging for instructions, self-monitoring, and automated personalized feedback versus a no-intervention control group among overweight or obese adults. Although none of the US adult studies reported positive findings beyond 9 months, the Finnish study showed that a text messaging intervention could result in significantly greater weight loss than no intervention up to 12 months (ie, intermediate term).

Also included in Table 2 is the only meta-analysis[66] to date that has focused on text messaging interventions for weight loss that showed that the pooled mean weight change was significantly better in intervention participants than in the control conditions. However, both the intervention and control subgroups were heterogeneous, and the funnel plot suggested a possible publication bias.

Khaylis and colleagues[69] identified 5 key components to efficacious technology-based weight loss interventions: use of a structured program, self-monitoring, feedback and communication, social support, and individual tailoring. These components found in the mobile technology interventions were shown to produce greater weight loss than in a randomized control group, although the extent and nature of the implementation of each component varied across studies. Additionally, all of the effective mobile interventions focused on calorie-reduced healthy eating, increased physical activity, and behavior change, which is consistent with the 2013 AHA/ACC/TOS guideline recommendation for comprehensive behavioral weight loss interventions.[57] Evidence from the reviewed RCTs suggests that these technologies may be effective when used alone or in conjunction with traditional weight loss intervention delivery modalities (eg, telephonic coach feedback, in-person group sessions, Web sites) to achieve modest weight loss of clinical significance in the short term.

Recommendations for Consumers and Healthcare Practitioners

During the past decade, the mHealth field has made great strides developing efficacious mobile weight loss approaches. Indeed, mobile interventions can produce weight loss in motivated populations, albeit at a lower magnitude relative to traditional treatment approaches. The characteristics of successful mobile interventions are quite comparable to those of their offline counterparts: The largest weight losses are produced by comprehensive, multicomponent interventions that are personally tailored, promote regular self-monitoring, and involve a qualified interventionist.[69] The accumulated evidence, although limited, supports intervention delivery through a range of technology channels (including the Web, SMS, e-mail, telephone, and IVR), with limited variability in the magnitude of weight loss outcomes.

Standard behavioral weight loss treatment is delivered by a trained healthcare professional to promote calorie-controlled healthy eating, increased physical activity, and behavior change in in-person group or individual sessions of a prescribed frequency and duration. It is encouraging that sufficient evidence derived mainly from studies of Internet-, e-mail–, and telephone-based interventions has accrued to buttress the 2013 AHA/ACC/TOS obesity treatment guideline recommending electronically delivered comprehensive weight loss programs encompassing personalized coach feedback as an acceptable, albeit possibly less effective, alternative to standard in-person treatment.

Our review finds that self-monitoring and automated personalized feedback are common features in the contemporary mobile weight loss interventions. On the basis of consistent findings from multiple RCTs of fair and good quality, the evidence is strong for short-term weight loss benefits in adults

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from text messaging interventions for self-monitoring and feedback when supported by other methods (coach telephone calls, Web sites, or private peer groups via social media)[74,83] or incorporated into an existing comprehensive lifestyle program,[84] with some evidence suggesting sustained intervention effectiveness through 12 months.[57] Importantly, there is no evidence to suggest that SMSs as a stand-alone intervention are effective. One RCT in the United Kingdom showed the effectiveness of a self-directed smartphone app as a stand-alone intervention in overweight and obese adults,[82] although the translatability of the results to US adults is unclear as a result of a lack of research.

Until more evidence emerges, health practitioners looking to implement or recommend mHealth interventions to their overweight and obese patients should ensure that the programs and tools they recommend include established evidence-based content and components of a comprehensive lifestyle intervention (ie, calorie-controlled healthy eating and increased physical activity with specified goals and behavioral strategies) and facilitate adoption of evidence-based weight loss behaviors (eg, self-monitoring, personalized feedback, and social support from coaches or peers). In the context of these programs, mobile technologies, particularly SMS/multimedia messaging service messaging and smartphone apps, may be the primary intervention modality when supported by other methods (Web sites or telephone calls). At present, no recommendations can be made for US consumers on the effectiveness of text messaging as a stand-alone intervention for weight loss or the effectiveness of any particular smartphone app.

Gaps and Recommendations for Future Research

There is great need for studies that explore mobile interventions in diverse contexts, particularly general consumer samples, and in clinical practice settings. Although great strides have been made, we do not have an answer to the question that consumers are most likely to ask: Are commercial mobile weight loss apps efficacious? We know little about the efficacy of the >1000 apps that purport to help consumers lose weight. Moreover, few, if any, research-tested apps have been widely disseminated or commercialized. Academic-industry partnerships are needed from the intervention development stage to formative evaluation to confirmatory research and then to dissemination and implementation.

The research literature investigating mobile weight loss interventions remains in its infancy, with many important questions yet to be answered. Indeed, we know little about how to best integrate mobile interventions into the primary care setting, where they might serve as adjuncts to weight loss counseling delivered by primary care or other providers such as dietitians or nurses. There are potentially significant opportunities to explore the integration of mobile technologies, given health system changes associated with the Affordable Care Act and the 2011 Center for Medicare and Medicaid Services decision to reimburse qualified providers for delivering intensive behavioral treatment for obesity. We need to also expand the range of populations that have been studied. Thus far, we know the least about those populations with the highest obesity rates and those who bear the greatest burden of obesity-associated disease: racial/ethnic minorities and the socioeconomically disadvantaged.[85] This fails to deliver on the promise of digital health approaches, which have potential for extending the reach of intervention approaches. Despite their higher levels of mobile phone ownership and use,[28,86] early evidence suggests that high-risk populations experience suboptimal weight losses,[85] as is often observed with traditional treatment approaches.

More work is necessary to assess and improve the magnitude of weight loss outcomes produced by mobile interventions and long-term maintenance of weight loss. A particular priority is identifying strategies to promote sustained user engagement. Indeed, across a large number of studies, weight loss outcomes have been shown to be dependent largely on the level of participant engagement.[63,72] Unfortunately, declining engagement and attrition (often as high as 40%–50%) are characteristic of digital health interventions.[87] Mobile interventions developed in research settings might benefit from leveraging the iterative design and testing conventions that are commonly used in the commercial market to promote user engagement. Furthermore, the most successful trials have combined interventionist support with a mobile intervention. We know much less about the efficacy of stand-alone mobile interventions, those that have the greatest potential for broad dissemination.

At present, there is considerable variability in the technologies, intervention components, design, and delivery schedules of mobile interventions. We know little about which technologies or intervention components, or combinations thereof, are best equipped to produce clinically meaningful weight loss. There does not appear to be substantial variability in the magnitude of weight loss outcomes in the mHealth approaches we reviewed. We have identified the following gaps and directions for future research:

- The applications of mobile technology for weight loss have been limited in conceptualization and narrow in implementation. Future mobile technology weight loss interventions should build on the best evidence of the efficacious core components of comprehensive lifestyle programs.
- Text messaging has been the primary delivery format researched to date; however, it is only one of a growing number of mobile delivery formats (eg, smartphone apps, wearable sensors that synchronize data with smartphones). We need to address the many pitfalls in the current mHealth approaches, for example, the absence of a theoretical basis, limited application of the best practices in technology design, low use of empirically supported behavioral strategies, and limited scientific rigor, by engaging in transdisciplinary collaboration and inclusion of the end users, the clinicians and patients, in all phases from the intervention development to implementation.
- Mixed methods research should be used to elucidate the frequency, timing and duration of various mobile delivery formats that can enhance the usability and acceptability of technology.
- Future work needs to focus on comparative effectiveness research using alternative designs, for example, equivalence and noninferiority trials. In addition, we need to use more flexible study designs that are able to provide

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answers within a shorter time frame than the conventional 5-year clinical trial when testing a delivery mode that will become obsolete before the end of the trial.[88]

- Finally, we need to capitalize on the currently available technologies that permit collection and transmission of data in real time to better learn about the behaviors and moods of individuals in their natural setting, referred to as ecological momentary assessment, which can inform the development of interventions that can be delivered in real time and thus provide support when individuals are in need of it.[89,90]

Use of mHealth Interventions to Increase Physical Activity

Regular physical activity is important in improving cardiovascular health. The Centers for Disease Control and Prevention, the American College of Sports Medicine, and the AHA recommend that adults participate in ≥30 minutes of moderate-intensity physical activity on most days of the week.[91] According to the 2008 Physical Activity Guidelines for Americans,[92] adults should avoid inactivity or extended periods of sedentary activity, do at least 150 minutes of moderate-intensity activity weekly, and do muscle-strengthening activities on at least 2 d/wk.[93] Sustained physical activity has many health benefits such as decreasing the risk for premature death, T2DM, stroke, some forms of cancer, osteoporosis, and depression.[94] There is sufficient evidence that physical activity can help reduce CVD risk factors such as high BP.[94]

Physical activity in the United States has significantly declined over the past 2 decades. Since the late 1980s, the proportion of adult women who report no leisure-time activity has increased from 19.1% to 51.7%, and the proportion of adult men reporting no leisure-time activity rose from 11.4% to 43.5%.[95] The participation in leisure-time activity is lowest in blacks, with >55% not meeting the guidelines, followed by those identifying as Hispanic or Latino, with >54% not meeting guidelines.[96] More than 66% of those who have not completed high school do not meet the 2008 Physical Activity Guidelines for Americans.[96]

Review of Evidence for the Efficacy of Mobile Technology–Based Interventions to Promote Physical Activity

We searched PubMed using the terms *physical activity*, *physically active*, *walk*, *aerobic*, *sport*, *lifestyle*, and *sedentary*. The literature search yielded 1490 studies. Of these, 1415 were excluded after review of title (n=797), abstract (n=528), or full text (n=122). Of the 122 that did not qualify on the basis of full text review, articles were excluded for the following reasons: 44 were focused on diabetes mellitus, 39 were focused on weight loss, and 41 did not meet RCT criteria. Therefore, 41 articles were eligible for the present review: 12 were literature reviews of physical activity for CVD prevention, 15 were studies validating technology, and 14 were RCTs that are detailed in Table 3. The literature search yielded studies reporting numerous types of technology that can be used for increasing physical activity: texting or SMS messaging on mobile phone (n=3), pedometer (n=1), e-mail (n=1), and Internet (n=9). Several studies included a combination of technologies.

Nine of the 14 studies reported significant increases in physical activity in the intervention group compared with the control condition.[98, 97,100–103,106,107,109] Overall, the technology that was used most often to increase physical activity was the Internet through Web sites, online tutorials, or networking opportunities. Many of the programs that used the Internet also used other forms of technology, including pedometers and feedback messages via e-mail. Of the 9 studies that used the Internet as the main intervention component, 5 reported significant differences between groups in increasing physical activity.[98,100,102,106,107] The outcomes differed in each study and included increases in step counts, increases in moderately vigorous physical activity, increases in moderate physical activity, and increases in minutes per week of physical activity. Two of the 14 studies examined the use of SMS,[103,109] and both reported significant differences between the intervention and control or comparative conditions.[103.109] Two additional studies reported testing the use of messages, either through a PDA or e-mail, and found significantly greater increases in physical activity in the intervention group compared with the control or nonintervention group.[97,101]

A systematic review of 26 studies published in 2014 by Bort-Roig et al[111] examined the use of smartphones to influence physical activity. Only 5 studies in the review assessed interventions for physical activity, and 4 reported an increase in steps per day. However, the studies were limited by small samples, with only 1 study having a sample size >50. A systematic review of 11 studies by Buchholz et al[112] in 2013 reported that <10 RCTs using SMS to target physical activity had been conducted across 7 countries and found that a small number of studies had examined the use of SMS for promotion of physical activity. The median effect size for differences in change scores between intervention and control groups for the studies was 0.50 but ranged from 0.20 to >1.00. The review noted that there was no evidence to suggest why there were such vast differences in the effect size.[112]

One area that is growing in acceptance among consumers is active video gaming or exergaming. The studies using this technology had some methodological limitations and thus were not included in this review. However, a systematic review by Peng et al[113] reported that laboratory studies have demonstrated that this technology is capable of providing light to moderate physical activity. However, only 3 studies in that review supported gaming as an effective tool to significantly increase physical activity or exercise attendance.

Most mobile technology interventions that have been reported in the published literature allow users to self-monitor physical activity by manually entering exercise bouts or total accumulated activity. However, more technologically sophisticated approaches for physical activity monitoring are rapidly becoming widely available. Physical activity tracking devices, also referred to as wearables, have become highly prevalent among consumers for self-monitoring daily activity. Most of these devices include accelerometers that capture users' duration and intensity of physical activity.[114] Some devices also include global positioning service (GPS) functionality that can capture the location of exercise sessions. Originally designed to be worn on the hip, wearables can now be placed comfortably in a range of locations (wrist, ankle, arm, shoe). The majority of current smartphones also include accelerometers and gyroscopes, allowing them to provide functionality similar to wearable devices. A host of third-party software

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Table 3. Description of Studies Using mHealth for Enhancing Physical Activity

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Plotnikoff et al,[97] 2005 Design: 2-group Outcome: Mets/min Setting: Workplace Country: Canada	N=2121 Int1: n=1566 Int2: n=555 Mean age (SD): Int1: 44.9 (6.2) y Int2: 45.0 (6.4) y Women: 73.5% White: NR Mean BMI (SD): Int1: 27.2 (5.7) kg/m^2 Int2: 27.0 (5.7) kg/m^2 Retention: NR	Int1: Received 1 PA and 1 parallel nutrition message per week for 12 wk Int2: Received no weekly messages	E-mail	Duration: 12 wk Contacts: Int group received a total of 24 messages over the 12 wk Intervention adherence: NR Interventionist: Int1: NR Int2: NR	Completer's analysis (n=2074) 12 wk: PA, mean MET/min: Int1: 683.68 Int2: 592.66 P<0.01
Hurling et al,[98] 2007 Design: Randomized, stratified, controlled trial Outcome: Δ in MPA (METs/wk) Setting: Community Country: United Kingdom	N=77 Int1: n=47 Int2: n=30 Mean age (SD): Int1: 40.5 (7.1) y Int2: 40.1 (7.7) y Women: 66% Mean BMI (SD): Int1: 26.2 (2.8) kg/m^2 Int2: 26.5 (4.1)kg/m^2 Retention: 100%	Int1: 9 wk of tailored solutions for barriers, mobile phone and e-mail reminders to exercise, message board, real-time feedback via Internet Int2: Verbal advice on recommended PA levels	Internet, mobile device, e-mail	Int lasted 9 wk Study duration: 12 wk Contacts: Int1: Not specified Intervention adherence: 85% of Int1 Ps logged onto Web site in first 4 wk, 75% logged in during the past 5 wk. Only 33% of participants accessed all components of the system Interventionist: Int1: Automated Int2: NR	ITT, ways to deal with missing data NR 12 wk: Accelerometer data, MPA, METs/wk, M (SE): Int1: 5.39 (0.01) Int2: 5.34 (0.01) P=0.02
Spittaels et al,[99] 2007 Design: 3-group RCT Outcome: Total PA Setting: Workplace Country: Belgium	N=526 Int1: n=174 Int2: n=175 Int3: n=177 Mean age (SD): 39.5 (8.5) y Women: 31% White: NR Mean BMI (SD): 24.4 (3.3) kg/m^2 Retention: 72%	Int1: Online tailored PA advice+stage-based reinforcement e-mails Int2: Online-tailored PA advice only Int3: Online nontailored standard PA advice	Internet, e-mail	Duration: 6 mo Contacts: Online-tailored PA advice+e-mail group received 5 e-mails over 8 wk Intervention adherence: Int1 group, 77% of Ps read the e-mails they received Interventionist: Int1: NR Int2: NR Int3: NR	Completer's analysis (n=379) 6 mo: Total PA, min/wk, M (SD): Int1: 776 (540) Int2: 682 (452) Int3: 708 (514) NSD
Dunton and Robertson,[100] 2008 Design: 2-group RCT Outcome: Δ in walking time and MVPA Setting: Community Country: United States	N=156 Int1: n=85 Int2: n=71 Mean age (SD): Int1: 42.8 (12.8) y Int2: 42.8 (10.5) y Women: 100% White: 65% Retention: 85%	Int1: Individually tailored PA plans via Internet, strategies to overcome barriers via Internet, 10 weekly follow-up e-mails Int2: Wait list	E-mail, Internet (Web site, Women's Fitness Planner)	Duration: 3 mo Contacts: 3 mo access to Web site, 10 weekly follow-up e-mail newsletters Intervention adherence: Int1: 6% reported not receiving weekly e-mails, 23% opened all e-mails, 8% opened none; 8% visited the Web site >10 times	ITT (MRCM, HGLM) 3 mo: Δ in walking time, mean min/wk: Int1: 69 Int2: 32 P=0.035 (1 tailed) MVPA Δ, mean min/wk Int1: +23 Int2: −25 P=0.045 (1 tailed)

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Table 3. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
				Int2: 11% reported not receiving the weekly newsletters Interventionist: Int1:NR Int2: NR	
King et al,[101] 2008 Design: 2-group RCT Outcome: min/wk of PA Setting: Community Country: United States	N=37 Int1: n=19 Int2: n=18 Mean age (SD): Int1: 60.7 (6.8) y Int2: 59.6 (7.6) y Women: 43% White: 78.5% Retention: 100%	Int1: PDA programmed to monitor PA levels twice per day for 8 wk. Daily and weekly individualized feedback, goal setting, and support Int2: Written PA educational materials	PDA	Duration: 8 wk Contacts: Int1: Daily contacts for 8 wk Intervention adherence: Int1 Ps completed an average of 68% of the PDA entries over the 8 wk Interventionist: Int1: NR Int2: NR	8 wk PA, min/wk, M (SD): Int1: 310.6 (267.4) Int2: 125.5 (267.8) *P*=0.048
Ferney et al,[102] 2009 Design: 2-group RCT Outcome: min/wk of PA Setting: Community Country: Australia	N=106 Int1: n=52 Int2: n=54 Mean age (SD): Int1: 51.7 (4.1) y Int2: 52.2 (5.0) y Women: 72% White: NR Retention: 88%	Int1: Ps received access to a neighborhood environment–focused Web site, received tailored information for increasing PA through e-mails Int2: Access to a motivational-information Web site, received nontailored e-mails	E-mail and Internet	Duration: 26 wk Contacts: Both groups: received 11 e-mails over the 26 wk Weeks 1–4: weekly e-mails Weeks 5–12: biweekly e-mails Weeks 13–26: monthly e-mails Intervention adherence: 13% of Ps used the self-monitoring tool and 25% sent e-mail to the activity counselor in Int group Interventionist: Int1: NR Int2: NR	ITT (BOCF) 26 wk: Total PA Δ, mean min/wk: Int1: +57.8 Int2: +13 Interaction effect: *P*<0.05
Fjeldsoe et al,[103] 2010 Design: 2-group RCT Outcome: Δ in MVPA and walking time Setting: Community Country: Australia	N=88 Int1: n=45 Int2: n=43 Mean age (SD): Int1: 28 (6) y Int2: 31 (6) y Women: 100% Education level <10 y: 17% Retention: 69%	Int1: A face-to-face PA goal-setting consultation, phone consultation, a goal-setting magnet, 3–5 personally tailored SMSs/wk, and a nominated support person who received SMSs each week Int2: Face-to-face information session	SMS	Duration: 13 wk Contacts: Int1: 0 and 6 wk: face-to-face PA goal-setting consultation 42 tailored SMSs on behavioral and cognitive strategies: Weeks 0–2: 5/wk Weeks 3–4: 4/wk Weeks 5–12: 3/wk 11 weekly goal check SMSs Int2: No contact apart from reminder telephone calls to confirm 6- and 13-wk assessments	ITT 13 wk: Δ in MVPA duration, M (SE) min/wk: Int1: 18.26 (24.94) Int2: 16.36 (25.53) *P*=0.26 Δ in walking duration, M (SE) min/wk: Int1: 16.67 (13.33) Int2: 0.34 (13.64) *P*=0.005

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Table 3. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
				Intervention adherence: 13 wk: 84% of Int1 group meeting MVPA goal 10 wk: 24% response to SMS 6 wk: 64% of Int2 Ps remaining in the trial (n=36) reported reading the SMSs and then storing them, 33% reported reading the SMSs and then deleting them, and 1 P (3%) reported deleting the SMS without reading them Interventionist: Int1: Trained behavioral counselor+automated Int2: Trained behavioral counselor	
Richardson et al,[104] 2010 Design: 2-group RCT Outcome: Step count Setting: Community Country: United States	N=324 Int1: n=254 Int2: n=70 Mean age (SD): 52.0 (11.4) y Women: 66% White: 86% Mean BMI (SD): 33.2 (6.2) kg/m^2 Retention: 76%	All Ps wore pedometers and had access to individually tailored messages, weekly goals Int1: Had access to post and read messages from other Ps Int2: Had no access to message board	Internet, pedometers	Duration: 16 wk Contacts: Int1: Received access to a community message board (reading and posting comments to group) for the 16-wk Int Intervention adherence: 65% of Int Ps were active in the community Int1 group uploaded pedometer data on 87% of days, Int2 group uploaded pedometer data on 75% of days Interventionist: Int1: NR Int2: NR	ITT (BOCF) 16 wk: Step counts, steps/d, M (SD): Int1: 6575 (3127) Int2: 5438 (2667) *P*=0.20
Aittasalo et al,[105] 2012 Design: 2-group RCT Outcome: Δ in walking time Setting: Community Country: Finland	N=241 Int: n=123 Control: n=118 Mean age (SD): Int1: 44.1 (9.4) y Int2: 45.3 (9.1) y Women: Int1: 71% Int2: 66% BMI : Int1: >25 kg/m^2: 63% Int2: >25 kg/m^2: 76% Retention: 77%	Int1: 1 group meeting, log-monitored pedometer use, 6 e-mail messages Int2: No intervention	Pedometers and e-mail	Duration: 12 mo Contacts: 6-mo treatment duration, 1 e-mail/mo, pedometer use daily Intervention adherence: 60% of Int Ps used pedometer regularly; 37% reported using pedometer irregularly for 6 mo E-mails reached 99% of Ps, 80% reported reading the messages Interventionist: Int1: NR Int2: NR	Completer's analysis (n=164) 12 mo: Total walking, min/wk, M (SD): Int: 521 (468) Control: 395 (319) *P*=NS % of Ps walking stairs: Int1: 88% Int2: 86% OR, 2.24 (95% CI, 0.94–5.31) % of Ps walking for leisure: Int1: 87% Int2: 76% OR, 2.07 (95% CI, 0.99–4.34)

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Table 3. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Reid et al,[106] 2012 Design: 2-grop RCT Outcome: steps/d; Δ in MVPA Setting: Community Country: Canada	N=223 Int1: n=115 Int2: n=108 Mean age (SD): 56.4 (9.0) y Women: 16.7% Mean BMI (SD): 29.3 (4.8) kg/m^2 Retention: 69%	Int1: Personally tailored PA plan on discharge from the hospital, provided access to a secure Web site for activity planning and tracking, 5 online tutorials, and e-mail access with an exercise specialist Int2: PA guidance from an attending cardiologist	Internet	Duration: 12 mo Contacts: 5 online tutorials over a 6-mo period and e-mail contact with an exercise specialist for Int1 group Intervention adherence: Mean No. of online tutorials completed by Int1 Ps: 2.7 of maximum of 5, 61.7% of Ps completed ≥3 of 5 tutorials 37 Int1 Ps e-mailed exercise specialist ≥1 time. Interventionist: Int1: Exercise specialist Int2: Cardiologist	ITT (multiple imputation of missing values) 12 mo: Step counts, steps/d, M (SD): Int1: 7392 (3365) Int2: 6750 (3366) *P*=0.023 Δ in MVPA, min/wk, M (SD): Int1: 201.4 (179.8) Int2: 163.4 (151.3) *P*=0.047
Bickmore et al,[107] 2013 Design: 2-group RCT Outcome: Steps/d Setting: Community Country: United States	N=263 Int1: n=132 Int2: n=131 Mean age (SD): 71.3 (5.4) y Women: 61% White: 37% High school diploma or less: 51% Retention: 86%	Int1: Mobile tablet computers with touch screens for 2 mo, directed to connect pedometers to tablet, interact with a computer-animated virtual exercise coach daily. Next 10 mo, given opportunity to interact with coach in a kiosk in clinic waiting room. Int2: Pedometer that only tracked step counts for an equivalent period of time	Internet via tablet with virtual exercise coach, pedometer	Duration: 12 mo Contacts: Ps interact with coach in a clinic kiosk between months 2 and 10 Intervention adherence: Int1 group interacted with coach 35.8 (19.7) times during the 60-d intervention phase and accessed the kiosk an average of 1.0 (2.9) times during the 10-mo follow-up. Interventionist: Int1: NR Int2: NR	Completer's analysis (n=200) 2 mo: Steps/d, M: Int1: 4041 Int2: 3499 *P*=0.01 Completer's analysis (n=128) 12 mo: Steps/d, M: Int1: 3861 Int2: 3383 *P*=0.09
Gotsis et al,[108] 2013 Design: Randomized, crossover design Outcome: Days/week of PA Setting: Community Country: United States	N=142 Int1: n=64 Int2: n=43 Mean age (SD): 35.6 (9.5) y Women: 67.6% Asian: 18% Hispanic: 28% Retention: 61%	Int1: Diary+game group: additional features: (1) rewards, (2) virtual character, (3) choosing virtual locations for wellness activities, (4) collecting virtual items, (5) wellness animations by spending points, (6) virtual character wellness activities as updates Int2: Diary group: (1) posting updates of PA, (2) private messages, (3) history posted, (4) viewing display of PA	Internet, social networking	Duration: 13 wk Contacts: Follow-up visits at 5–8 and 10–13 wk Intervention adherence: Ps accessed the Web site every other day, with the number of total logins ranging from 1–102 (mean, 38.00; SD, 22.31) Interventionist: Int1: NR Int2: NR	Completer's analysis (n=87) 13 wk: Δ in PA, d/wk, M: Int1: 3.43 Int2: 0.88 *P*=0.08
Kim et al,[109] 2013 Design: 2-group RCT	N=45 Int1: n=30 Int2: n=15	Int1: Pedometer and manual to record steps plus motivational SMSs 3 times/d, 3 d/wk for 6 wk	SMS	Duration: 6 wk Contacts: 3 times/d for 3 d/wk for 6 wk	Completer's analysis (n=36)

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Table 3. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BMI, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Outcome: Steps/day Setting: Community Country: United States	Mean age (SD): Int1: 69.3 (7.3) y Int2: 70.6 (7.5) y Women: 80% Black: 100% Mean BMI (SD): Int1: 30.2 (7.0) kg/m^2 Int2: 31.4 (7.4) kg/m^2 Retention: 80%	Int2: Pedometer and manual to record steps but not SMSs		Intervention adherence: NR Interventionist: Int1: Automated Int2: NR	6 wk: Δ in step count, M: Int1: +679 Int2: +398 P<0.05
King et al,[110] 2014 Design: 2-group RCT Outcome: Δ in MVPA Setting: Community Country: United States	N=148 Int1: n=73 Int2: n=75 Mean age (SD): 60 (5.5) y Women: NR White: NR Mean BMI (SD): 29.5 (5.4) kg/m^2 Retention: 78%	Int1: 12-mo home-based MVPA, primarily walking, program delivered via a trained telephone counselor (human advice arm) Int2: Similar program delivered via an automated, computer interactive telephone system (automated advice arm)	Automated, computer interactive telephone system	Duration: 12 mo; study, 18 mo Contacts: Ps in both groups received one 30-min in-person, one-on-one instructional session followed by a similar number of advisor-initiated telephone contacts across the 12-mo period Intervention adherence: NR Interventionist: Int1: Trained phone counselor Int2: Automated	ITT (BOCF) 18 mo: Int1: 167.0±135.6 Int2: 145.2±134.5 P=0.41
Systematic review and meta-analysis					
Bort-Roig etal,[111] 2014 Design: Systematic review of 26 RCTs	NR Among the 26 reviewed articles, 17 implemented and evaluated a smartphone-based intervention, 5 used single group pre-post designs and 2 used pre-post designs relative to a control or comparison group	Interventions that used smartphones to influence PA	Smartphone	NR	4 studies (3 pre-post and 1 comparative) reported PA increases (12–42 participants, 800–1104 steps/d, 2 wk–6 mo), and 1 case-control study reported PA maintenance (n=200 participants; >10 000 steps/d) over 3 mo

Automated indicates without a clinician who generates, tailors, or modifies the output; baseline, 0; BMI, body mass index; BOCF, baseline observation carried forward; CI, confidence interval; Δ, change or difference; HGLM, hierarchical generalized linear model; Int, intervention group; ITT, intention to treat; M, mean; MET, metabolic equivalent; MPA, moderate physical activity; MRCM, multilevel random coefficient modeling; MVPA, moderate- to vigorous-intensity physical activity; n, subgroups; N, total sample; NR, not reported; NS, not significant; NSD, not significantly different; OR, odds ratio; P, participant; PA, physical activity; PDA, personal digital assistant; RCT, randomized control trial; and SMS, short message service.

applications have emerged to leverage this technology, and some mobile operating systems include physical activity tracking as a default functionality. There is emerging evidence that combining physical activity tracking devices with group behavioral treatments will produce larger weight loss outcomes than either the device or group treatment alone.[76]

Gaps and Recommendations for Future Research

A large number of smartphone applications and wearable devices (FitBit, JawBone) exist that are designed to monitor, track, and promote physical activity, but none of these apps have been compared with the established methods of objectively measuring physical activity such as accelerometers and thus have no empirical basis. More than 20% of US adults are tracking their health with some form of technology, and 1 in 5 adults with a smartphone has at least 1 health application. The most popular health applications (38% of downloads) are those related to exercise, pedometer use, and heart rate monitoring.[115] However, with the exception of the Bodymedia armband, which was used as part of a weight loss intervention study reported by Shuger et al,[76] none of the studies identified in this review tested these wearable monitors for efficacy. Therefore, it is recommended that future studies include the use of these commercially available devices in RCTs to determine their efficacy in improving physical activity. The data on established accuracy for these consumer wearable physical activity trackers are limited. One study examining the accuracy and precision of these devices (eg, Bodymedia FIT, Fitbit Zip, Jawbone Up) reported

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that most wearable devices yielded reasonably accurate reporting of energy expenditure, within about 10% to 15% error, compared with a portable metabolic analyzer.[116] Equivalence testing revealed that the estimates from the Bodymedia FIT and Fitbit Zip were within the 10% equivalence zone around the indirect calorimetry estimate.[116] Thus, rigorous RCTs with diverse populations are needed to establish an empirical basis for the use of the apps and mobile tracking devices for improving physical activity or reducing sedentary activity.

The realm where there seems to have been a prolific explosion of wearable devices and trackers is physical activity; however, compared with some of the other health-related areas, the research conducted to date is limited. The following list outlines the gaps and recommendations for future research in the area of mHealth interventions for promoting physical activity:

- Little is known about the use of wearable consumer devices, although many adults are using this technology. Therefore, large-scale, randomized trials of diverse populations need to be conducted to test the efficacy of this technology in increasing physical activity or reducing sedentary behavior.
- Health-related apps are among the most popular downloads, yet they are not being rigorously tested. Therefore, commercially available apps that are downloaded by the public need to be validated and examined for efficacy and acceptability and for sustainability of engagement. Only then can we provide the consumer with evidence for their use.
- Similarly, additional testing is recommended for the use of exergaming to increase physical activity levels in both children and adults.
- The Internet was the platform tested most often for the delivery of technology targeting increased physical activity. Thus, other platforms need to be tested for promoting physical activity, for example, SMS or more recently developed approaches that can be delivered on a smartphone or tablet.

Use of mHealth for Smoking Cessation

Tobacco use remains the most significant preventable risk factor for CVD. The AHA Task Force on Risk Reduction noted that approximately a third of CVD deaths are attributable to smoking and that a substantial and rapid decrease in risk results from smoking cessation.[117] Although there are a number of effective pharmacological and behavioral interventions for smoking cessation, the delivery of these interventions has been inconsistent. Practice guidelines for smoking cessation incorporate the 5 As: ask, advise, assess, assist, and arrange.[118] Although most healthcare providers report asking about smoking and advising their patients to quit, they are much less likely to assess willingness to quit, assist with cessation, or arrange follow-up.[119] Given the limitations of smoking cessation delivered by health professionals, technologies have been leveraged to facilitate the delivery of smoking cessation interventions. Early approaches used the Internet to deliver these interventions,[120] and current and reputable Internet interventions such as smokefree.gov are available.[121] The advent of mobile technologies provides potential delivery advantages over Internet interventions via desktop or laptop computers.

Smoking urges occur frequently throughout the day in response to various triggers, and indoor smoking bans have moved smoking behavior outside, away from computers used at work and home. Mobile devices are therefore more likely to be available when smokers experience the urge to smoke and can deliver interventions at these times. These mobile devices also offer the promise of "just-in-time adaptive interventions" that adapt interventions on the basis of context and potentially preempt smoking behavior by anticipating when urges are likely to occur.[122]

Current commercially available mobile apps for smoking cessation have generally failed to deliver empirically supported interventions or to make optimal use of the capabilities of mobile phones. A series of studies by Abroms and colleagues[123,124] have shown that most commercially available smoking cessation apps do not adhere to practice guidelines for smoking cessation. Some of these practice guidelines, developed for delivery by healthcare professionals, may not be appropriate criteria for mobile interventions. For instance, should a smoking cessation mobile app ask about smoking, or is it reasonable to assume that, if a user has downloaded an app for quitting smoking, he or she is a smoker? Additionally, some empirically supported approaches that are amenable to a computerized intervention such as scheduled gradual reduction of smoking[125] may not have been included in the practice guidelines because of the difficulty of delivery by healthcare professionals. Even with these caveats, commercially available mobile apps for smoking cessation are generally incomplete and lack empirical basis. Abroms and colleagues[123,124] have documented that, although some smoking cessation apps are downloaded more than a million times per month, smartphone apps adhere, on average, to only about a third of the practice guidelines for smoking cessation interventions.

Although most commercially available smoking cessation apps are incomplete or lack empirical support, there has been considerable research on the efficacy of mobile interventions for smoking cessation that we review below. Until quite recently, these empirically tested interventions developed by smoking cessation researchers were not commercially available. Much of the initial research on SMS for smoking cessation occurred outside of the United States, and the programs, if available at all, are available only in those countries. Additionally, researchers developing these mobile smoking cessation programs often did not partner with commercial entities capable of marketing the program once evaluated; however, there are recent examples of commercially available programs developed by researchers.[126,127]

Review of Evidence for the Efficacy of Mobile Technology–Based Interventions to Promote Smoking Cessation

We searched PubMed for the years 2004 to 2014 using the terms *quit smoke*; *stop smoke*; *stopped smoke*; *ceased smoke*; *smoking cessation*; *cigarette smoke*; *smokeless tobacco*; *smoker*; *tobacco cessation*; *tobacco use*; *nicotine replacement*; *nicotine gum*; *nicotine lozenge*; *nicotine nasal*; *nicotine patch*; and *nicotine inhalant*. These terms were cross-referenced with the mobile technology terms described previously. This search resulted in 286 identified articles. Of these, most (211) were not relevant to mobile technologies for smoking cessation. These were

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predominately Internet-based interventions or studies that used mobile technologies for recruitment or measurement purposes but not for intervention. Of the remaining 85 publications, 14 were RCTs of mobile technologies for smoking cessation, and these trials are described in Table 4. The remaining reports of mobile technologies for smoking cessation were a range of studies including descriptions of design and development; reports of feasibility, acceptability, and usability data; uncontrolled trials; and various systematic reviews. For completeness, 2 Cochrane meta-analyses of this area[140,141] are included in the table.

SMS for Smoking Cessation

Most of the research on mobile smoking cessation interventions has focused on text messaging as the delivery medium. Why was SMS the focus when there are so many other delivery mediums on today's smartphones? First, many of the early studies using mobile phones for smoking cessation[128,142] predate the advent of the smartphone; hence, SMS was one of the few functions available on feature phones for the delivery of interventions. Second, SMS is a relatively inexpensive development environment that will run on any cell phone, whereas a smartphone app needs to be developed for each operating system (eg, Android, iOS) and updated with each operating system update. Third, although smartphone use is increasing dramatically and is now at >50% in the United States,[29] smartphone use was reported as lowest by adults in lower socioeconomic groups.[143] Smoking rates are disproportionately higher in lower socioeconomic groups[144] that remain predominately feature phone users. Recent Pew statistics show, however, that Hispanics and blacks have higher rates of smartphone use than whites, indicating the demographic shift in mobile phone use that could make smartphone apps a viable medium for cessation interventions targeting minorities.[30]

Cochrane Meta-Analysis

Controlled studies of mobile phone programs for smoking cessation have been summarized in a Cochrane meta-analysis[140] and update.[141] The details of studies reviewed in these 2 meta-analyses are listed in Table 4. For both reviews, the primary outcome was smoking abstinence of ≥6 months and included both sustained and point prevalence abstinence and both self-reported and biochemically validated smoking status. However, the number of studies reviewed was 4 and 5, respectively, in the 2 meta-analyses, and there was considerable heterogeneity of effect across studies.

The initial Cochrane review[140] identified 9 articles relevant to smoking cessation via mobile phones in which the mobile intervention was a core component, not just an adjunct to an Internet or in-person program. Of these, 4 were small, nonrandomized feasibility trials, and 2 had insufficient follow-up for inclusion. Of the 4 studies included in the meta-analysis, 2 assessed the same text messaging program delivered in 2 different countries,[128,131] and the remaining 2 trials[129,130] evaluated a combined Internet and mobile phone intervention. The 4 studies lacked long-term follow-up or biochemical validation in more than a small subsample of participants, but all 4 studies showed significantly greater abstinence at 6 months compared with control subjects (Table 4 provides details).

In the 2012 update of the Cochrane review,[141] 5 trials were included: a video messaging mobile phone intervention,[133] a Web-based quit coach and text messaging intervention,[136] and 3 evaluations of an SMS or text messaging intervention.[128,131,132] Pooled across these 5 studies, the relative risk for long-term quit rates was 1.71. Among the studies reviewed in the Cochrane update, the large, well-controlled UK study by Free and colleagues[132] accounted for more than half (50.45%) of the subjects in the meta-analysis. In this single-blind trial, 5800 smokers willing to quit were randomly assigned either to a mobile phone text program (txt2stop) that included behavior change support and motivational messages or to a control group that received SMSs unrelated to quitting smoking. On the basis of biochemically verified continuous abstinence at 6 months, quit rates were significantly greater in the txt2stop (10.7%) than in the control group (4.9%), and the abstinence rates were similar when those lost to follow-up were treated as smokers. Since the Cochrane update in 2012, there have been a number of RCTs of smoking cessation programs delivered via mobile phone technologies, and they are listed in Table 4.

Special Populations

There are limited intervention options for pregnant smokers. In a preliminary trial comparing smoking cessation programs in pregnant smokers,[134] there were no significant differences in self-reported smoking abstinence between groups who received educational materials and those who received tailored SMSs. Further research is needed to identify minimal risk interventions that are effective for pregnant smokers.

Likewise, young adults with low education are a particularly vulnerable population for smoking that warrants additional research on both prevention and cessation interventions. Two recent studies[138,139] compared the effectiveness of technology-based smoking cessation interventions with educational pamphlets in adolescent vocational students. Neither study reported significant differences in self-reported abstinence after intervention between the groups receiving text messaging interventions and those receiving paper-based educational materials; however, the sample sizes in these 2 studies may have been inadequate to detect differences.

Recent Studies

Ybarra and colleagues[135] first studied an SMS program delivered in Turkey and more recently studied the effects of their SMS intervention in a study of young adult smokers in the United States.[126] Although the intervention produced significantly higher abstinence rates at 4 weeks, these differences were not sustained at 3 months.

Abroms and colleagues[127] recently published a controlled trial of Text2Quit, an automated, tailored, interactive text messaging program for smoking cessation. In contrast to many previous programs that primarily push out texts, the Text2Quit program is interactive and prompts users to track smoking and report cravings. Using keyword texts, users have the ability to reset quit dates, request help with a craving, obtain program and data summaries, and indicate if they have slipped and smoked. Mailed saliva cotinine–verified point prevalence abstinence at 6 months showed an 11% abstinence rate for intervention compared with 5% for control subjects. In contrast to the studies and programs in the earlier Cochrane reviews, this study was conducted in the United States and evaluated a program that is commercially available to smokers in the United States.

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Table 4. Description of Studies Using mHealth for Smoking Cessation

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Rodgers et al,[128] 2005 2-group RCT Primary Outcome: 6 wk abstinence Secondary outcomes: 12 wk and 26 wk abstinence Setting: Community Country: New Zealand	N=1705 Int1: n=853 Int2: n=852 Women: 58.5% Median age (IQR): 22 (19–30) y European ethnicity: 63.0% Maori: 20.8% Pacific Islander: 3.5% Other: 12.7% Baseline Fagerstrom Score, median (IQR): 5 (3–6) Mean (SD) of number of CPDs: 15 (3) Average previous quit attempts: 2/person Lost to follow-up: 6 wk: Int1: 46 Int2: 35 Retention: 95.2% 26 wk: Int1: 261 Int2: 179 Retention: 74.2%	Int1: Quit day established within 30 d, received personalized texts. Ps received free SMSs for 1 mo after quit date. Int2: Texts related to appreciation for participating, Ps received 1 mo of free SMSs on completion (not dependent on quit status). Neither group was advised to cease using other resources for quitting smoking. SMS was an add-on to standard treatment.	SMS	Duration: 26 wk (6 mo) Contacts: Int1: 5 SMSs/d for the first 5 wk then 3 SMSs/wk until end of 6 mo Int2: 1 SMS every 2 wk Follow-up via phone at 6, 12, and 24 wk for both groups Interventionist: Int1: Automated, tailored SMS Int2: Automated, nontailored SMS	ITT (assuming missing=smoking) Abstinence: 6 wk: Int1: 239 (28%) Int2: 109 (13%) RR, 2.2 (95% CI, 1.79–2.70) *P*<0.001 12 wk: Int1: 247 (20%) Int2: 160 (29%) RR, 1.55 (95% CI, 1.30–1.84) *P*<0.001 26 wk: Int1: 216 (25%) Int2: 202 (24%) RR, 1.07 (95% CI 0.91–1.26) *P*=NS Of 83 Int1 and 42 Int2 self-reported abstainers at 6 wk asked to provide saliva for cotinine assay, bioverification confirmed abstinence in: Int1: 17 (20.5%) Int2: 6 (14.3%) RR, 2.84 (95% CI, 1.12–7.16), *P*=0.02
Brendryen et al,[129] 2008 Design: 2-group RCT Outcome: 1-, 3-, 6-, 12-mo 7-d no-puff self-report abstinence Setting: Community Country: Norway	N=290 Int1: n=144 Int2: n=146 Mean age (SD): Int1: 39.5 (11.0) y Int2: 39.7 (10.8) y Women: 50% Mean (SD) cigarettes smoked per day: Int1: 16.6 (7.2) Int2: 17.6 (7.0) College degree: Int1: 49% Int2: 52% Mean (SD) nicotine dependence: Int1: 4.5 (2.3) Int2: 4.6 (2.2) Retention: 77.9% Int1: 81.9% Int2: 74.0%	Int1: Happy Endings group: Received Happy Endings (Internet and mobile phone smoking cessation program) Int2: Received 44-page self-help book	E-mail, Web pages, IVR, SMS, craving hotline	Duration: 12 mo Contacts: 1-, 3-, 6-, and 12-mo abstinence reports Intervention adherence: Number of Web and phone responses 1 mo: Int1: n=139 Int2: n=127 3 mo: Int1: n=135 Int2: n=131 6 mo: Int1: n=124 Int2: n=120 12 mo: Int1: n=131 Int2: n=123 Discontinued treatment: Int1: n=57 (47%) Interventionist: Int1: Automated Int2: booklet	ITT, missing assumed=smoking; 7-d no-puff point abstinence: 1 mo: Int1: 42% Int2: 17% *P*=0.001 3 mo: Int1: 35% Int2: 16% *P*=0.001 6 mo: Int1: 29% Int2: 14% *P*=0.002 12 mo: Int1: 33% Int2: 23% *P*=0.07 Complete case analysis Repeated point abstinence: 1+3 mo: Int1: 30% Int2: 12% *P*=0.001

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Table 4. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
					1+3+6 mo: Int1: 24% Int2: 7% *P*=0.001 1+3+6+12 mo: Int1: 20% Int2: 7% *P*=0.002
Brendryen and Kraft,[130] 2008 Design:2-group RCT Outcome: 1-, 3-, 6-, 12-mo 7-d no-puff self-report abstinence Setting: Community Country: Norway	N=396 Int1: n=197 Int2: n=199 Mean age (SD): Int1 35.9 (10.0) y Int2: 36.4 (10.5) y Women: Int1: 50.8% Int2: 19.8% College degree: Int1: 42.1% Int2: 39.7% CPD: Int1: 18.3±5.9 Int2: 18.1±5.8 Precessation self-efficacy: Int1: 4.9±1.3 Int2: 5.1±1.3 Retention: Int1: 88% Int2: 84%	Int1: Happy Endings Internet and cell phone–based smoking cessation program, 400+ contacts by e-mail, Web pages, IVR, and SMS Int2: 44-page self-help booklet Both groups offered NRT	E-mail, Web pages, IVR, SMS	Duration: 54 wk Contacts: 1-, 3-, 6-, and 12-mo abstinence reports NRT adherence: Int1: 93% Int2: 87% *P*=NS Discontinued treatment: Int1: n=45 (23%) Interventionist: Int1: Automated Int2: NA	ITT, missing assumed=smoking; 7-d no-puff point prevalence abstinences: 1 mo: Int1: 50.3% Int2: 29.6% *P*=0.001 3 mo: Int1: 44.7% Int2: 28.6% *P*=0.001 6 mo: Int1: 37.1% Int2: 21.6% *P*=0.001 12 mo: Int1: 37.6% Int2: 24.1% *P*=0.005
Free et al,[131] 2009 Design: 2-group RCT Outcome: 4-wk and 6-mo self-reported abstinence Setting: Community Country: United Kingdom	N=200 Mean age (SD): 36 (9) y Women: 38% Median No. of cigarettes smoked: 20/d Manual occupations: 33% Retention: 92%	Int1: Received SMS smoking cessation program (txt2stop) made up of motivational messages and behavioral-change support. Int2: Received SMS messages unrelated to quitting smoking	Mobile phone SMS	Duration: 6 mo Contacts: Int1 group received daily SMSs starting at randomization with a countdown to quit day and then 5 messages/d for 4 wk after the quit day. Intervention continued with a maintenance package of 3 SMSs/wk for 26 wk. Int2 group received simple, short, generic SMS every 2 wk. Intervention adherence: Response rate: At 4 wk: 96% At 6 wk: 92% Interventionist: Int1: Automated Int2: Automated	Completer sample, self-report point prevalence abstinence 4 wk: Int1: 26% Int2: 13% *P*=0.02 RR, 2.08 (95% CI, 1.11–3.89) 6 mo: Int1: 8.5% Int2: 6.7% *P*=0.6

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Table 4. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Free et al,[132] 2011 Design: Single-blind 2-group RCT Outcome: 6 mo biochemically verified smoking abstinence Setting: Community Country: United Kingdom	N=5800 Int1: n=2911 Int2: n=2881 Women: 45% Mean age (SD): Int1: 36.8 (11.0) y Int2: 36.9 (11.1) y White: Int1: 89% Int2: 88% Previous quit attempts (1–5 times): Int1: 74% Int2: 76% Fagerstrom score ≤5: Int1: 60% Int2: 60% Retention: 95%	Int1: SMS txt2stop mobile phone smoking cessation program. Set quit date within 2 wk, received 5 SMSs/d first 5 wk, then 3/wk for next 26 wk Participants can text back "crave" or "lapse" and receive supportive instant message Int2: Received SMS unrelated to quitting, every 2 wk, short, SMSs related to the importance of participation	Mobile phone SMS	Duration: 6 mo Contact: 4 wk and 6 mo Intervention adherence: Received entire intervention Int1: n=2509 Int2: n=2734 Interventionist: Int1: Automated Int2:Automated	ITT, missing data multiple imputations 6 mo: Self-reported continuous abstinence biologically verified by postal salivary cotinine or in-person exhaled carbon monoxide: Int1: 10.7% Int2: 4.9% *P*<0.0001
Whittaker et al,[133] 2011 Design: 2-group RCT Outcome: 6-mo self-reported continuous abstinence Setting: Community Country: New Zealand	N=226 Predominantly Maori Int1: n=110 Int2: n=116 Mean age (SD): Int1: 27.5 (9.5) y Int2: 16.6 (7.8) y Women: Int1: 53% Int2: 42% Retention: Int1: 63% Int2: 78%	Int1: Quit date prompt and 2 SMSs/d, video messages on cessation Int2: Quit date prompt and 2 SMSs/d, video	SMS and video messaging to mobile phones; Internet	Duration: 12 wk Contacts: 1–3 messages/d, reduced to alternating days during maintenance Intervention adherence: 29% used the text "crave" function; 16% used the text "relapse" function requesting assistance Interventionist: Int1: Automated Int2: Automated	ITT, missing assumed=smoking 6 mo: Continuous abstinence: Int1: 26.4% Int2: 27.6% *P*=NS
Naughton et al,[134] 2012 2-group RCT Outcomes: 12-wk self-reported and cotinine-validated 7-d point prevalence abstinence and cognitive determinants of quitting Feasibility and acceptability of a tailored self-help SC intervention for pregnant smokers (MiQuit) Setting: Community Country: United Kingdom	N=207 pregnant Int1: n=102 Int2: n=105 White: 100% <21-wk gestation Mean age (SD): Int1: 27.2 (6.4) y Int2: 26.5 (6.2) y 12-wk retention: Int1: n=86 (84%) Int2: n=89 (85%)	Int1: MiQuit sent a 4-d, colored, tailored, self-help leaflet via mail and received tailored SMS Int2: Received a nontailored leaflet via mail; received no tailored SMS but did receive assessment SMS at 3 and 7 wk	SMS	Duration: 11 wk Total contacts: A 4-page leaflet for both intervention groups; 2 assessment SMSs, 1 at 3 wk and 1 at 7 wk; 3-mo follow-up for acceptability, cognitive determinants of quitting, and smoking outcomes. Int1 also received ≈80 tailored SMSs over 11 wk; 0, 1, or 2 SMSs were sent daily at various times over 11 wk Feasibility: 94% (81/86; 95% CI, 89–99) of MiQuit participants and 80% (71/89; 95% CI, 71–88) of control subjects received both SMS and the leaflet	ITT, missing assumed=smoking 12 wk: Self-reported abstinence: Int1: 22.9% Int2: 19.6% OR, 1.22 (95% CI, 0.62–2.41); *P*=NS Cotinine-validated abstinence: Int1: 12.5% Int2: 7.8%; OR, 1.68 (95% CI, 0.66–4.31; *P*=NS) Process outcomes: Int1 more likely to set a quit date (*P*=0.049) and have higher levels of self-efficacy (*P*=0.024), harm beliefs (*P*=0.052), and determination to quit (*P*=0.019)

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Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
				Acceptability: 9% (95% CI, 4–15) of MiQuit participants opted to discontinue SMS Interventionist: Int1: Automated tailored SMS Int2: Automated assessment SMS	
Ybarra et al,[135] 2012 2-group RCT Primary Outcome: Bioverified sustained abstinence at 3 mo Setting: Community Country: Ankara, Turkey	N=151 Int1: n=76 Int2: n=75 Mean age (SD): Int1: 36.1 (9.5) y Int2: 35.6 (10.3) y Women: Int1: 46.1% Int2: 32.0% Mean CPD (SD): Int1: 18.7 (7.2) Int2: 20.4 (9.2) Fagerstrom score mean (SD): Int1: 4.8 (2.3) Int2: 4.9 (2.5) Retention: Int1: n=46 (61%) Int2: n=51 (68%)	Int1: 6-wk daily messages aimed at quitting skills. Messages automated except for 2 and 7 d after quit day, when RAs manually assigned Ps to content paths based on whether they had relapsed or had maintained quitting. Int2: 7-page brochure	SMS	Duration: 3 mo Int duration: 6 wk Contacts: Int1: Varied by P (dependent on stage of change and whether relapse occurred; range, 91–146) Int2: No SMS Each group had in-person visits at baseline, 4 wk after quit day, and at 3-mo follow-up Intervention adherence: NR Interventionist: Int1: Automated+RA manually assigned to content path Int2: NA	ITT, missing assumed=smoking 3-mo cessation bioverified by carbon monoxide: Int1: 11% Int2: 5% *P*=NS Secondary outcome: Smoking <20 Int1: 17% Int2: 0% *P*=0.02
Borland et al,[136] 2013 Design: 5-group RCT Outcome: self-reported continuous abstinence at 6 mo Setting: Community Country: Australia	N=3530 Int1: n=809 Int2: n=756 Int3: n=785 Int4: n=758 Int5: n=422 Mean age (range): 42.1 (18–80) y Women: 60% Currently smoking: 87.4% Average No. of cigarettes smoked: 16.9/d Retention: 86.5%	5 conditions: Int1: QuitCoach personalized tailored Internet-delivered advice program Int2: onQ, an interactive automated SMS program Int3: An integration of both QuitCoach and onQ Int4: A choice of either Internet or SMS alone or the combined program Int5: Minimal Int and was offered a simple informational Web site	Internet and SMS	Duration: 7 mo Contacts: Int. lasted 7 mo, follow-up surveys at 1 and 7 mo Intervention adherence: Used intervention: 42.5% Tried it: 14.6% Did not use it: 43% Interventionist: Int1: Automated Int2: Automated Int3: Automated Int4: Automated Int5: NA	ITT, assuming missing=smoking, LOCF, and completers' analysis 6-mo sustained abstinence: Int1: 9.0% Int2: 8.7% Int3: 8.7% Int4: 9.1% Int5: 6.2% *P*=NS
Ali et al,[137] 2013 Design: Randomized pre-post 2-group design Outcome: 7-d point prevalence self-reported abstinence at 6 wk, 30-d point prevalence abstinence at 12 wk Setting: Community Country: United States	N=102 Mean age (SD): Int1: 25.5 (NR) y Int2: 24.3 (NR) y Women: Int1: 45% Int2: 57% White: Int1: 70% Int2: 76%	Int1: Smokers received smartphone application (REQ-Mobile) with interactive tools Int2: Assigned to the onQ group who received a SMS system	Smartphone application (REQ-Mobile), SMS system (onQ)	Duration: 12 wk Contacts: Pretest, 6-wk posttest, and 12-wk posttest smoker-reported smoking status Intervention adherence: 60% used allocated service Interventionist: Int1: Interactive online Int2: Automated SMS	ITT, assuming missing=smoking and completers' analyses 6 wk (completers' analysis, n=66): 7-d point prevalence abstinence: Int1: 30% Int2: 58% *P*=0.03

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Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
	Cigarettes smoked per day: Int1: 16.8 Int2: 17.1 Attempted to quit in the past year: Int1: 66% Int2: 71% Retention: 67%				12 wk: ITT 30-d point prevalence abstinence: Int1: 18% Int2: 31% *P*=NS Completers' 30-d point prevalence abstinence: Int1: 27% Int2: 46% *P*=NS
Haug et al,[138] 2013 Design: 2-group cluster randomized design Outcome: 7-d self-reported abstinence at 6 mo Setting: Vocational schools Country: Switzerland	N=755 in 178 classes Int1: n=383 in 88 classes Int2: n=372 in 90 classes Mean age (SD): Int1: 18.2 (2.4) y Int2: 18.3 (2.2) y Women: 49% Smoking status: Occasional: 29% Daily: 71% Retention at 6 mo: Int1: 79.3% Int2: 71.0%	Int1: Online assessment, weekly SMS assessment, 2 weekly tailored messages, integrated quit day and relapse prevention Int2: No intervention	SMS to mobile phones	Duration: 3 mo Contacts: 3 SMS per week Intervention adherence: 2.4% unsubscribed Mean number of replies to weekly assessment: 6.5 of a 11 possible replies Interventionist: Int1: Automated Int2: Assessment	ITT with 30 imputed data sets 6 mo: 7-d self-reported abstinence: Int1: 12.5% Int2: 9.6% OR, 1.03 (95% CI, 0.59-1.79; *P*=NS)
Shi et al,[139] 2013 Design: 2-group cluster randomized design Outcome: 7-d self-reported abstinence at 12 wk Setting: Vocational schools Country: China	N=179 in 6 schools Int1: n=92 in 3 schools Int2: n=87 in 3 schools Mean age (SD): Int1: 17.6 (NA) y Int2: 16.9 (NA) y Women: Int1: 7% Int2: 2% Smoking status: Occasional: 29% Daily: 71% Retention at 12 wk: Int1: 83% Int2: 53%	Int1: Tailored daily SMS based on transtheoretical model Int2: Smoking cessation pamphlet	SMS to mobile phones	Duration: 12 wk Contacts: Daily SMS Intervention adherence: 87 participants completed the intervention, receiving a median of 129 messages and sending a median of 32 messages Interventionist: Int1: Automated daily SMS Int2: NA	ITT, assuming missing=smoking 12 wk: 7 day self-reported abstinence: Int1: 14% Int2: 8% OR, 1.8 (95% CI, 0.7–4.2)
Ybarra et al,[126] 2013 Design: 2-group RCT Primary outcome: 3-mo continuous abstinence verified by significant other Setting: Community Country: United States	N=164 Int1: n=101 Int2: n=63 Mean age (SD): Int1: 21.6 (2.1) y Int2: 21.6 (2.1) y Women Int1: 44% Int2: 28% White: Int1: 65% Int2: 41% Retention at 3 mo: Int1: 81/101 (80%) Int2: 51/63 (81%)	Int1: 6-wk SMS (Stop My Smoking) intervention provided tailored SMS based on relapse status and quit day date. Included buddy support and craving support. Int2: Attention-matched control group with similar number of SMS as intervention but aimed at improving sleep and PA. Not tailored to quit day status. Buddy support and craving support not available.	SMS	Duration: 3 mo Intervention: 6 wk Contacts: 2 follow-up appointments: 1 at 6 wk and 1 at 3 mo Varying No. of SMS sent per day to each group, which was dependent on time point in the study Interventionist: Int1: Automated SMS+buddy Int2: Automated SMS	ITT, with missing assumed=smoking 4 wk: Quit rate: Int1: 39% Int2: 21%, OR, 3.33 (95% CI, 1.48–7.45) 3 mo: Quit rate: Int1: 40% Int2: 30%, OR, 1.59 (95% CI, 0.78–3.21)

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Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome
Abroms et al,[127] 2014 Design: 2-group RCT Outcome: 6-mo biochemically validated point prevalence abstinence Setting: Community Country: United States	N=503 Int1: n=262 Int2: n=241 Mean age (SD): 35.7 (10.7) y Women: 66% Average No. of cigarettes/d: 17.3 Retention: 76% at 6 mo	Int1: Interactive SMS timed and tailored around the user's quit date Int2: Receive smokefree.gov site until site included SMS, then changed to Clearing the Air Web site	SMS; Internet	Duration: 3-mo push SMS followed by 3 mo of SMS on request Contacts: 2 SMS/d on average but up to 5/d around quit date Intervention adherence: 85% received at least 1 SMS Mean of 28 SMS received of those who received at least 1 Interventionist: Int1: Interactive SMS Int2: Automated	ITT, missing assumed=smoking Point prevalence abstinence at 6 mo bioverified by saliva cotinine: Int1: 11.1% Int2: 5.0% RR, 2.22 (95% CI, 1.16–4.26); $P<0.05$
Systematic reviews and meta-analyses					
Whittaker et al,[140] 2009 Meta-analysis of MEDLINE, EMBASE, Cinahl, PsycINFO, The Cochrane Library, the National Research Register, and ClinicalTrials Register Outcome: self-reported point prevalence abstinence	4 trials split into 2 analyses N1=1905 Int1: n1=954 Con1: n1=951 N2=696 Int2: n2=348 Con2: n2=348 Included smokers of any age who wanted to quit and used any type of mobile phone–based intervention. Retention range for all 4 studies: Int: 69%–92% Control: 79%–92%	4 studies included (in 5 articles) Used the Mantel-Haenszel risk ratio fixed-effect method in which there was no evidence of substantial statistical heterogeneity as assessed by the $I(2)$ statistic	Analysis 1: SMS Analysis 2: SMS+Internet	Analysis 1: Studies were 6-mo duration Analysis 2: Studies were 12-mo duration Intervention contacts varied by study Intervention adherence: NR	Analysis 1: When the studies were pooled, significant increase in short-term self-reported abstinence (RR, 2.18; 95% CI, 1.8–2.65) Analysis 2: When the data from the Internet and mobile phone programs were pooled, there were significant increases in short- and long-term self-reported quitting (RR, 2.03; 95% CI, 1.40–2.94)
Whittaker et al,[141] 2012 Meta-analysis of the Cochrane Tobacco Addiction Group Specialized Register Outcome: 6 mo smoking abstinence, allowing 3 lapses or 5 cigarettes	5 randomized or quasi-randomized trials N=9100 Int1: n=4730 Int2: n=4370 Retention at 6 mo varied across studies: Int1: 68%–94% Int2: 78%–97%	Used the Mantel-Haenszel risk ratio fixed-effect method. There was substantial statistical heterogeneity as indicated by $I(2)$ statistic: $I(2)=79\%$	3 studies used SMS, which was adapted over the course of the studies for different populations and contexts; 1 multiarm study used SMS intervention and an Internet QuitCoach separately and in combination; 1 study used video messaging delivered via mobile phone	Study duration: ≥6 mo Adherence rates: NR	Mobile phone interventions increase long-term quit rates vs control programs at 6 mo (RR, 1.71; 95% CI, 1.47–1.99; >9000 participants)

Automated indicates without a clinician who generates, tailors, or modifies the output; CI, confidence interval; CPD, cigarettes per day; Δ, change or difference; Int, intervention group; IQR, interquartile range; ITT, intention to treat; IVR, interactive voice response; LOCF, last observation carried forward; M, mean; n, subgroups; N, total sample; NA, not applicable; NR, not reported; NRT, nicotine replacement therapy; OR, odds ratio; P, participant; PA, physical activity; RA, research assistant; RCT, randomized, controlled trial; RR, relative risk; SC, smoking cessation; and SMS, short message service.

Gaps and Recommendations for Future Research

- There is substantial evidence that mobile phone apps for smoking cessation, particularly SMS programs, are effective for smoking cessation. The effects found for mobile phone smoking cessation interventions are comparable to the effects found for other smoking cessation interventions, including nicotine replacement therapies.[145]
- The considerable heterogeneity of this evidence, however, suggests that not all text messaging programs are

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created equal and that there is considerable individual variability in response to these programs. Therefore, although these text messaging programs have sufficient empirical support to be recommended to patients interested in quitting smoking, the selection of text messaging intervention may matter.

- Unfortunately, many of these empirically supported text messaging programs were developed and evaluated outside the United States and are not available, commercially or otherwise, to US smokers. This lack of access in the United States to proven text messaging programs is beginning to change. Abroms and colleagues[127] recently published evidence for their Text2Quit program, which is commercially available.
- Although hundreds of smartphone applications for smoking cessation are commercially available, there is considerable evidence that these applications have a limited empirical basis,[123,124] and we could find no published study testing the efficacy of any of these commercially available smartphone apps. In the 1 study that compared smartphone apps with text messaging,[137] text messaging produced better quit rates. Although it is clearly premature to recommend any smartphone application for smoking cessation at this time, smartphone applications hold potential future promise as smoking cessation interventions. Smartphones provide a range of potential features and functions not available via text messaging modalities that have not been adequately leveraged to date for smoking cessation. For example, movement and location sensors in smartphones could be used to learn the contexts in which users smoke and deliver interventions preemptively before the urge to smoke occurs.[122] Sensors connected to smartphones such as carbon monoxide monitors[146] provide objective measures of smoking status.
- Another promising approach that builds on the use of smartphones is ecological momentary interventions, an approach to the delivery of interventions to people during their everyday lives (ie, in real time) and in natural settings (ie, the real world).[147] This approach is gaining increasing attention as a potential approach across multiple behavioral domains and was tested in an earlier study for smoking cessation with significantly higher quit rates in the intervention group than in the control group at 6 and 12 weeks, but this rate was not sustained at 26 weeks.[128,147] Ongoing studies are testing this approach with the currently available smartphone technology.
- One critical but inadequately researched area is how to engage smokers to initiate the use of these mobile phone SMS programs. The well-controlled, population-based, multiarm trial of Borland and colleagues[136] had fewer than half of the intervention participants engage with the intervention on even a minimal basis. In the follow-up study by Riley and colleagues,[148] participants were assisted with program initialization as a result of the findings of an earlier trial in which 37% of the participants completed baseline measures but failed to initialize the SMS program on their own.[142] Bock and colleagues[148a] conducted focus groups on preferences for a SMS-based smoking cessation program for potential users. Participants recommended including social networking components, greater control of program output via online profile, and more interactive text messaging features. In parallel with research on the efficacy of these mobile phone programs for those who engage with them, research on how to engage smokers and keep them engaged in these programs is also needed.

Summary and Recommendations

Smoking cessation via mobile phone intervention is a relatively young area of research with only 10 years of published literature. Within this short period, however, a number of large, well-controlled studies have shown that SMS programs produce approximately double the abstinence rates of minimal intervention control conditions. Despite this success, the failure rate from these programs is still unacceptably high (≈90% fail to quit at 6 months), and the heterogeneity of effect across studies suggests that certain varieties of SMS interventions may work better than others and in certain populations differentially from others. Until more is known on optimal intervention components of SMS for smoking cessation and on which smokers are more likely to benefit from these approaches, the current literature is able to support only that SMS interventions should be considered along with other efficacious smoking cessation interventions for smokers trying to quit.

Use of mHealth for Self-Management of Diabetes Mellitus

Diabetes mellitus occurs in 9.3% of the US population (29.1 million individuals). Of increasing concern is the number of US adults with undiagnosed diabetes mellitus (8.1 million) or prediabetes (86 million).[149] CVD and stroke are serious complications of diabetes mellitus. The majority of US adults ≥18 years of age with diabetes mellitus have CVD risk factors, including high BP (71%), high cholesterol (65%),[159] and obesity (70%).[150] Although death rates for heart attack and stroke have decreased, adults with diabetes mellitus are twice as likely to be hospitalized for and to die of these diseases as people who do not have diabetes mellitus. Because people with diabetes mellitus are living longer, the prevalence of obesity is not abating, and the rate of diagnosed new cases is increasing (7.8–12.0 per 1000 in 2012, depending on age), scientists expect that the number of people with diabetes mellitus and CVD will continue to rise. However, because the rates of survival after heart attack and stroke continue to improve, more people with diabetes mellitus will continue to live into older age with comorbidities of CVD and diabetes mellitus. According to the joint statement of the AHA and American Diabetes Association, glycemic control in diabetes mellitus management for both type 1 diabetes mellitus and T2DM is important in risk reduction for CVD events. Hemoglobin A_{1c} (HbA_{1c}) is the clinical measure of glycemic control, and the self-monitoring of blood glucose is done by the consumer (patient). A general population target of HbA_{1c} <7% is recommended for clinician consideration and health plan targets, but an individualized approach to glycemic control at the patient level is suggested. It is important to note that the consumer (patient) role in glycemic control requires problem solving and daily decision making about multiple behaviors (eating, activity, monitoring, and medication taking), and the

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healthcare provider role is collaborating with the patient to prescribe the appropriate diabetes mellitus medication(s) and monitoring the impact.[151]

Consumer/Patient Perspective

There are thousands of mobile applications for supporting diabetes mellitus self-management, serving primarily as tracking and reference apps. Few have been evaluated, and even fewer have demonstrated outcomes.[137] In fact, <1% of mobile applications have been evaluated through research. It can be hoped that increased federal and private foundation investments in mHealth and behavioral, clinical, and health system interventions combined with new regulatory requirements will provide consumers and providers with evidence of effectiveness or what works.

A number of pharmacological and lifestyle interventions for diabetes mellitus management have been confirmed by multiple RCTs; however, only 48.7% of patients meet the HbA_{1c}, BP, and lipid goals for diabetes mellitus care, and only 14.3% meet these 3 measures and the goals for tobacco use.[137] The National Standards for Diabetes Self-Management Education/Support, jointly published by the American Diabetes Association and the American Association of Diabetes Educators, incorporate the American Association of Diabetes Educators 7 self-care behaviors (physical activity, healthy eating, taking medication, monitoring, self-management problem solving, reducing risks, and healthy coping) as essential behaviors for improving diabetes mellitus self-management.[152,153]

Mobile technologies for diabetes mellitis self-management can be categorized in the following way: SMS apps via mobile phone, diabetes mellitus medical devices (eg, blood glucose meters, insulin pumps) with connectivity to smartphone apps, and bidirectional data sharing between patients and providers through smartphones. This classification did not exist when most of the reviewed articles were published. Interventions delivered via mobile technologies and directed at consumers may be supported by behavior change theories or principles, for example, the self-efficacy theory. However, most studies have limited theoretical foundations or lack an empirical basis. Moreover, healthcare providers lack knowledge about what apps are available or how to evaluate them and thus are hesitant to recommend them.[23]

Although large, primary care RCTs of mobile diabetes mellitus management are limited, smaller studies addressing the feasibility, usability, and acceptability have generally identified the following components as essential to successful diabetes mellitus management: personalized engagement, provision of actionable feedback for consumers, and connection with providers or healthcare systems. Additional contributors to usability include mobile technologies to support community health workers and peer-supported self-care behaviors.[155]

Review of Evidence for the Efficacy of Mobile Technology–Based Interventions to Promote Self-Management of Diabetes Mellitus

We searched PubMed for the years 2004 to 2014 using the terms *type 2 diabetes*; *NIDDM*; *maturity onset diabetes*; *adult onset diabetes*; *non-insulin dependent*; *noninsulin dependent*; *slow onset diabetes*; *stable diabetes*; *hyperinsulinemia*; *hyperinsulinism*; *insulin resistance*; *hyperglycemia*; *glucose intolerance*; *metabolic syndrome*; *metabolic X syndrome*; *dysmetabolic syndrome*; and *metabolic cardiovascular syndrome*. These terms were cross-referenced with the mobile technology terms described previously. This search resulted in 242 identified articles. Of these, 83 were not relevant to the use of mobile technology with diabetes mellitus, and 159 were reviewed further. Of these 159 references identified, 142 were excluded after review of the title, abstract, and full text. Similar to other sections of this review, mobile technologies may target multiple behaviors singly or in combination to improve numerous clinical and behavioral outcomes. Therefore, for this review, we focused on studies with change in the clinical metric of HbA_{1c} as the primary outcome, considered the gold standard in diabetes mellitus improvement. Seventeen articles were eligible for this review, and 10 of these 17 were international studies.

The types of mobile technologies used for diabetes mellitus self-management research interventions include mobile platforms with diabetes mellitus-specific software apps or SMS. Table 5 provides details of the RCTs using these mobile tools that we reviewed.

When evaluating interventions, we considered an HbA_{1c} reduction of at least 0.3% as a clinically meaningful treatment effect[175] and a 1% decrease in HbA_{1c} as a clinically meaningful indicator of reduced risk of diabetes mellitus complications on the basis of the Diabetes Control and Complications Trial (DCCT) and UK Prospective Diabetes Study (UKPDS) clinical trials.[176,177] One US study[170] reported a significantly greater HbA_{1c} decrease in the intervention group than in the control group. Quinn et al[170] evaluated a mobile phone software application with a patient and provider Web portal. The average HbA_{1c} decline over the 1-year intervention was 1.9% for the intervention group versus 0.7% for the control group, a difference of 1.2% ($P<0.001$). Among 4 studies[156,158,159,165] using SMS alone and SMS with Web tracking, 3 studies reported significant changes in HbA_{1c}.[156,159,165] Six studies used a mixture of technologies for the intervention, including mobile phones, Internet, Web portals, SMS, and glucose meters that provided messaging.[164,166,168,171,178]

We also include in Table 5 a systematic review by Liang et al[173] and a Cochrane review.[174] The systematic review included 22 trials. The meta-analysis of 1657 participants showed that mobile phone interventions for diabetes mellitus self-management reduced HbA_{1c} values by a mean of 0.5% over a median of 6 months of follow-up. A subgroup analysis of 11 studies of patients with T2DM reported a significantly greater reduction in HbA_{1c} compared with studies of those with type 1 diabetes mellitus (0.8% [9 mmol/mol] versus 0.3% [3 mmol/mol]; $P=0.02$). The authors reported that the effect of the mobile phone intervention did not differ significantly by other participant characteristics or intervention strategies. The Cochrane review reported computer-based diabetes mellitus self-management interventions for adults with T2DM in 4 studies. The interventions addressed in this review included those using computer-based software applications that were based on user input (touch screen or other clinic support), desktop computer–based and mobile phone–based interventions. The Cochrane review also included other outcomes besides HbA_{1c}, for example, health-related quality of life, death resulting from any cause, depression, adverse

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Table 5. Description of Studies Using mHealth for Blood Glucose Control

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
Kim[156] and Kim and Jeong,[157] 2007 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=60 Int1: n=30 Int2: n=30 Mean age (SD): Int1: 46.8 (8.8) y Int2: 47.5 (9.1) y Women: 56.9% HbA_{1c} (%), M (SD): Int1: 8.1 (1.7) Int2: 7.6 (1.1) Retention: 85%	Int1: Ps tracked their blood glucose levels and medications on a Web portal and received weekly feedback from a diabetes nurse Int2: Usual care	SMS with Web-based tracking of glucose levels	Duration: 6 mo Contacts: Int1: Weekly feedback via SMS Int2: 1–2 times during the 6 mo Intervention adherence: NR Interventionist: Int1: Diabetes nurse Int2: Clinician	Completer's analysis (n=51) 3 mo: HbA_{1c} (%), M (SD): In1t: 6.9 (1.0) Int2: 7.7 (0.9) $P<0.05$ 6 mo: HbA_{1c} (%), M (SD): Int1: 7.0 (1.4) Int2: 7.7 (0.9) Group×time: $P=0.008$
Faridi et al,[158] 2008 Design: 2-group RCT Outcome: Δ in HbA_{1c} Setting: Community Country: United States	N=30 nt1: n=15 Int2: n=15 Mean age (SD): 56 (9.7) y Women: 63% White: NR HbA_{1c} (%), M (SD): Int1: 6.4 (0.6) Int2: 6.5 (0.7) Retention: 13%	Int1: 1-day training and 3-mo intervention using the NICHE system (transmits glucometer and pedometer data to online server which then transmits tailored feedback to Ps via text messaging). Int2: Continued standard diabetes mellitus self-management and tracked step count with pedometer	Internet and SMS	Duration: 3 mo Contacts: 1-y training workshop on NICHE device; Ps required to upload once-daily glucose and pedometer data daily and receive tailored SMS messages Intervention adherence: 13.3% completely adherent; 26.7% adherent for 1–2 mo; 26.7% adherent for 1 wk; 33.3% did not transmit any information Interventionist: Int1: Nurse practitioners Int2: NR	ITT 3 mo: HbA_{1c} Δ, %, M (SD): Int1: −0.1 (0.3) Int2: 0.3 (1.0) P=NS
Kim and Song[159] and Kim and Kim,[160] 2008 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Outpatient clinic Country: South Korea	N=40 Int1: n =20 Int2: n=20 Mean age (SD): Int1: 45.5(9.1) y Int2: 48.5(8.0) y Women: 52.9% White: NR HbA_{1c} (%), M (SD): Int1: 8.1(1.9) Int2: 7.6 (0.7) Retention: 85%	Int1: Ps recorded daily glucose values in Web portal; received weekly SMS feedback from diabetes educator Int2: Usual care	SMS feedback based on Web-based tracking portal	Duration: 12 mo Contacts: Int1: Weekly feedback via SMS Int2: Contact at 3 and 6 mo Intervention adherence: NR Interventionist: Int1: Diabetes physician+diabetes educator Int2: Diabetes physician+diabetes educator	Completer's analysis (n=34) 6 mo: HbA_{1c} (%), M (SD): Int1: 7.1 (1.5) Int2: 7.7 (0.5) Group×time: $P=0.04$ 12 mo: HbA_{1c} (%), M (SD): Int1: 6.7 (0.8) Int2: 8.2 (0.5) Group×time: $P=0.02$
Yoon and Kim,[161] 2008 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=60 Int1: n=30 Int2: n=30 Mean age (SD): Int1: 46.8 (8.8) y Int2: 47.5 (9.1) y Women: 56.9 % HbA_{1c} (%), M (SD): Int1: 8.1 (1.7) Int2: 7.6 (1.1) Retention: 85.0%	Int1: Completed self-monitoring blood glucose levels, entered values and medication data on a Webpage; this information was used to tailor recommendations to Ps. Tailored messages sent via SMS and Internet, weekly medication adjustments communicated to the Ps' physician.	SMS and Web	Duration: 12 mo Contacts: Baseline and posttest assessments; blood draws at baseline, 3, 6, 9, and 12 mo Int1: Had 52 messages over 1 y Int2: Same assessment time points as Int1, but in-person contact at outpatient clinic was variable per Ps	Completer's analysis (n=51) 12 mo: HbA_{1c} (%), M (SD): Int1: 6.8 (0.8) Int2: 8.4 (1.0) P=0.001

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Table 5. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
		Int2: Met with endocrinologist in person at an outpatient clinic and was given basic information		Intervention adherence: Assessment attendance (completed posttest): Int1: 83.3% Int2: 86.7% Interventionist: Int1: Physicians and nurses Int2: Endocrinologist	
Istepanian et al,[162] 2009 Design: 2-group RCT outcome: HbA_{1c} (%) Setting: Community Country: United Kingdom	N=137 Int1: n=72 Int2: n=65 Mean age (SD): Int1: 60 (12) y Int2: 57 (13) y Women: NR White: 34% HbA_{1c} (%), M (SD): Int1: 7.9 (1.5) Int2: 8.1 (1.6) Retention: 64%	Int1: SMBG via Bluetooth upload; data were reviewed by research team; analysis was sent via mail to Ps and PCP. Ps had hotline access to research team for questions Int2: Standard care	Glucometer adapted to send data via Bluetooth to mobile phone	Duration: 9 mo Contacts: Int1 P's blood glucose measurements transmitted wirelessly; research clinicians sent letters to Ps and their providers with treatment recommendations Intervention adherence: NR Interventionist: Int1: Clinicians Int2: Clinicians	ITT Mean 9 mo HbA_{1c} (%), M (SD): Int1: 7.9 (NR) Int2: 8.2 (NR) *P*=0.17 Completer's analysis (n=87) HbA_{1c} (%), M (SD): Int2: 7.8 (NR) Int2: 8.4 (NR) *P*=0.06
Rodríguez-Idígoras et al,[163] 2009 Design: 2-group RCT outcome: HbA_{1c} Setting: Community Country: Spain	N=328 Int1: n=161 Int2: n=167 Mean age (95% CI): Int1: 63.3 (61.6– 5.0) Int2: 64,5 (63.0–66.1) Women: 48% White: NR HbA_{1c} (%), M (95% CI): Int1: 7.6 (7.4–7.9) Int2: 7.4 (7.2–7.6) Retention: 91%	Int1: Ps provided mobile phone and tele-assistance system (DIABECOM) using real-time transmission of blood glucose results, with immediate reply when necessary, and telephone consultations Int2: Standard clinical care	Mobile phone, tele-assistance system	Duration: 12 mo Contacts: Ps made average of 3 calls/mo; average, 2.6 reminder or follow-up calls from call center Intervention adherence: Use of tele-assistance system (%): Int1: 62% Int 2: NA Interventionist: Int1: Physician and a nurse specializing in diabetes and diabetes education Int2: NR	ITT (n=321) 12 mo: HbA_{1c} (%), M (95% CI): Int1: 7.4 (7.2–7.6) Int2: 7.4 (7.1–7.6) *P*=0.34
Yoo et al,[164] 2009 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=123 Int1: n=62 Int2: n=61 Mean age (SD): Int1: 57.0 (9.1) y Int2: 59.4 (8.4) y Women: 47.2% HbA_{1c} (%), M (SD): Int1 7.6 (0.9) Int2: 7.4 (0.9) Retention: 90.2%	Int1: UCDC system using mobile phones and Web-based interaction. UCDC included device attached to mobile phone that transmitted blood glucose data. Ps received SMS reminder to check blood glucose, also tips via SMS 3 times/d. Physicians could track the Ps' data and send individualized messages as needed. Int2: Usual Care. Ps visited according to usual schedule and received usual care in the outpatient setting	SMS and Internet	Duration: 3 mo Contacts: Int1: 2 alarms daily to remind Ps to measure blood glucose values and blood pressure and 1 alarm daily for weight. Additionally, each P received at least 3 SMSs daily Int2: Dependent on usual care routine. Each P was seen at baseline and at 3 mo to collect anthropometric and laboratory data	Completer's analysis (n=111) 3 mo: HbA_{1c} (%), M (SD): Int1: 7.1 (0.8) Int2: 7.6 (1.0) Group×time: *P*=0.001

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Table 5. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
				Intervention adherence: Int1: Sent in glucose readings 1.84±0.31 times/d with a compliance rate of 92.2±15.4% Blood pressure readings sent in 1.72±0.32 times/d with a compliance rate of 86.0±16.2% Weight measurements were sent in 0.87±0.20 times/d with a compliance rate of 87.4±20.1% Interventionist: Int1: Automated Int2: Physician	
Kim et al,[165] 2010 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=100 Int1: n=50 Int2: n=50 Mean age (SD): Int1: 47.8 (9.6) y Int2: 49.0 (10.7) y Women: 50% White: NR HbA_{1c} (%), M (SD): Int1: 9.8 (1.3) Int2: 9.8 (1.2) Retention: 92%	Int1: Received daily insulin dose adjustments via SMS based on logged data sent via mobile phone to Web site Int2: Self-adjusted basal insulin according to daily self-monitored capillary FBG measurements using glucometers	SMS with Web tracking	Duration: 12 wk Contacts: Ps' dose adjustments were reviewed by the investigator at 4- and 8-wk clinical visits. Intervention adherence: No. of checks of blood glucose monitoring: Int1: 51.8 (16.1) checks Int2: 42.2 (13.2) checks *P*=0.002 Interventionist: Int1: Automated Int:2: NR	Completer's analysis (n=92) 12 wk: HbA_{1c} (%), M (SD): Int1: 7.4 (0.7) Int2: 7.8 (0.8) *P*=0.02 Δ in weight (kg), M (SD): Int1: 2.4 (3.0) Int2: 2.2 (2.8) *P*=0.65
Noh et al,[166] 2010 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=44 Int1: n=24 Int2: n=20 Mean age (SD): Int1: 42.5 (10.6) y Int2: 42.3 (7.6) y Women: 22.5% White: NR HbA_{1c} (%), M (SD): Int1: 9.0 (2.3) Int2: 8.6 (1.2) Retention: 90.9%	Int1: eMOD, a Web-based ubiquitous information system, for mobile phone users along with a Web site for Internet users to provide diabetes education Int2: educational books with contents similar to that in eMOD Web site	eMOD mobile and Web application for diabetes education	Duration: 6 mo Contacts: All Ps visited their physicians every 2 mo Intervention adherence: Int1: eMOD system was accessed via computer 160 times during the study period Interventionist: Int1: Physicians Int2: Physicians	Completer's analysis (n=40) 6 mo: HbA_{1c} (%), M (SD): Int1: 7.5 (1.4) Int2: 8.1(0.3) *P*=0.23
Carter et al,[167] 2011 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: United States	N=74 Mean age (SD): Int1: 52 (NR) Int2: 49 (NR) Women: 64% Black: 100% HbA_{1c} (%), M (SD): Int1: 9.0 (NR) Int2: 8.8 (NR)	Int1: Ps were provided laptop with peripherals (scale, BP cuff, glucometer) with automatic transmission to Internet; biweekly video conferencing with nurse; access to Internet-based self-management module with tailored action plan,	Internet, wireless scales, BP cuffs, and glucometers	Duration: 9 mo Contacts: Ps weigh daily, check BP weekly, SMBG 3 times daily; biweekly 30-minute video conferences with telehealth nurse to develop tailored action plan Intervention adherence: NR	Completer's analysis (n=47) 9 mo: HbA_{1c} (%), M (SD): Int1: 6.8 (NR) Int2: 7.9 (NR) *P*<0.05 Δ in weight (lb), M: Int1: −73.0 Int2: −58.1 *P*<0.05

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Table 5. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
	Retention: 64% Int1: n=26 Int2: n=21	health education module, and social networking module Int2: standard clinical care		Interventionist: Int1: Nurse Int2: NR	Δ in systolic BP, M: Int1: −7 Int2: −8 *P*>0.05 Δ in diastolic BP, M: Int1: −15 Int2: −14 *P*>0.05
Lim et al,[168] 2011 Design: 3-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=154 Int1: n=51 Int2: n=51 Int3: n=52 Mean age (SD): Int1: 67.2 (4.1) y Int2: 67.2 (4.4) y Int3: 68.1 (5.5) y Women: 55.8% HbA_{1c} (%), M (SD): Int1: 7.8 (1.0) Int2: 7.9 (0.9) Int3: 7.9 (0.8) Retention: 93.5%	All Ps were standardized with diabetes mellitus education Int1: Usual healthcare: SMBG+SMS feedback Int2: SMBG Int3: usual care	SMS, Gluco Dr Supersensor, AGM-2200, Allmedicus	Duration: 6 mo Contacts: All Ps visited the outpatient clinic every 3 mo for an interview conducted by their physician and provided a blood sample Intervention adherence: Frequency of SMBG, n/wk: Int1: 10.5 (5.1) Int2: 8.2 (4.2) Int3 2.4 (3.3) Interventionist: Int1: Automated+specialized diabetes management team consisting of well-trained professionals, including diabetologists, nurses, dietitians, and exercise trainers; organized and directed patient education Int2: Specialized diabetes management team consisting of well-trained professionals, including diabetologists, nurses, dietitians, and exercise trainers; organized and directed patient education Int3: NR	Completer's analysis (n=144) 6 mo: HbA_{1c} (%), M (SD): Int1: 7.4 (1.0) Int2: 7.7 (1.0) Int3: 7.8 (1.0) *P*<0.05 (Int1 vs Int2 and Int1 vs Int3)
Quinn et al,[169] 2008 Design: RCT Outcome: Δ in HbA_{1c} (%) Setting: Primary care practices Country: United States	N=30 Int1: n=NR Int2: n=NR Mean age (SD): 51.04 (11.03) y Women: 65% Black: 62%	Int1: Mobile phone-based diabetes management software system used with Web-based data analytics and therapy optimization tools Int2: Usual care by PCP	Mobile phone	Duration: 3 mo Total contacts: Baseline, 3-mo follow-up Intervention adherence: NR Interventionist: Int1: Healthcare providers Int2: PCP	Complete analysis (n=26) Δ in HbA_{1c} (%), M (95% CI): Int1: 2.03% Int2: 0.68% (*P*<0.02, 1 tailed)
Quinn et al,[170] 2011 Design: Cluster RCT Outcome: Δ in HbA_{1c} (%) Setting: Primary care practices Country: United States	N=213 Int1: n=62 Int2: n=38 Int3: n=33 Int4: n=80	Int1: CO. Ps received educational and motivational messages after putting data into the phone. Ps also received supplemental electronic messages within the application, generated by "virtual educators" based on longitudinal data trends	App designed for diabetes management, Web portal	Duration: 12 mo Total contacts: Baseline, 12-mo follow-up. Charts reviewed for HbA_{1c} at 3, 6, and 9 mo Intervention adherence: NR	Completer's analysis (n=163) 12 mo: Δ in HbA_{1c} (%), M (95%CI): Int1: −0.7 (−1.1 to −0.3) Int2: −1.6 (−2.3 to −1.0) Int3: −1.2 (−1.8 to −0.5) Int4: −1.9 (−2.3 to −1.5)

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Table 5. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
	Mean age (SD): Int1: 53.2(8.4) y Int2: 52.8(8.0) y Int3: 53.7(8.2) y Int4: 52(8.0) y Women: 44.2% White: 52.8% HbA1c (%), M (SD): Int1: 9.2 (1.7) Int2: 9.3 (1.8) Int3: 9.0 (1.8) Int4: 9.9 (2.1) Retention: 76.5%	Int2: Coach PCP portal. Same as CO except PCP was able to view raw data and discuss with the Ps Int3: Coach PCP portal with decision support. Same as CO except PCPs received Ps' analyzed data that summarized glycemic and metabolic control, adherence to medication, self-management skills; related to evidence-based guidelines and standards of care. Int4: Usual care		Interventionist: Int1: Coach Int2: Coach diabetes educators+PCP Int3: Coach diabetes educators+PCP Int4: Usual care clinicians	*P*=0.001 (Int4 vs Int1), *P*=0.02 (Int2 vs Int1), *P*=0.40 (Int3 vs Int1) Δ in systolic BP (mm Hg), M (95% CI): Int1: 2 (−3 to 7) Int2: 4 (−4 to 11) Int3: 2 (−6 to 10) Int 4: −2 (−6 to 3) *P*>0.05 Δ in diastolic BP (mm Hg), M (95% CI): Int1: 1 (−2 to 4) Int2: 2 (−2 to 7) Int3: −2 (−6 to 3) Int4: −1 (−4 to 2) *P*>0.05
Orsama et al,[171] 2013 Design: 2-group RCT Outcome: Δ in HbA_{1c} (%) Setting: Community Country: Finland	N=55 Int1: n=29 Int2: n=26 Mean age (SD): Int1: 61.5 (9.1) y Int2: 62.3 (6.5) y Women: 45.8% HbA_{1c} (%), M (SD): Int1: 7.1 (1.5) Int2: 6.9 (1.6) Retention: 87.3%	Int1: Ps participated in remote patient reporting of health status parameters and linked health behavior change feedback (called Monica) Int2: Received standard of care, including diabetes education and healthcare provider counseling	Internet, mobile phone	Duration: 10 mo Contacts: Int1: Ps received real time feedback Intervention adherence: NR Interventionist: Int1: Automated+healthcare provider Int2: Healthcare provider	Completer's analysis (n=48) 10 mo: Δ in HbA_{1c} (%), M (95% CI): Int1: −0.40 (−0.67 to −0.14) Int2: 0.04 (−0.23 to 0.30) *P*=0.02 Δ in weight (kg), M (95% CI): Int1: −2.1 (−3.6 to −0.6) Int2: 0.4 (−1.1 to 1.9) *P*=0.02 Δ in systolic BP (mm Hg), M (95% CI): Int1: −13.5 (−21.3 to −5.8) Int2: −17.1 (−24.3 to −9.9) *P*=0.51 Δ in diastolic BP (mm Hg), M (95% CI): Int1: −7.3 (−10.9 to −3.8) Int2: −9.5 (−12.9 to −6.2) *P*=0.38
Forjuoh et al,[172] 2014 Design: 4-group RCT Outcome: Δ in HbA_{1c} Setting: Community Country: United States	N=376 Int1: n=101 Int2: n=81 Int3: n=99 Int4: n=95 Mean age (SD): 57.6 (10.9) y Women: 55% White: 64%	Int1: Chronic Disease Self-Management Program Int2: PDA Int3: Chronic Disease Self-Management Program+PDA Int4: Usual care	PDA with diabetes pilot software	Duration: 12 mo Contacts: Int1: 6 wk, 2.5 h/wk classroom-based program for diabetes self-management Int2: Diabetes pilot software on a PDA (with training; software tracks glucose, BP, medications, PA, dietary intake)	Completer's analysis (n=263) 12 mo: HbA_{1c} Δ, %, M (SD) Int1: −0.7 (NR) Int2: −1.1 (NR) Int3: −0.7 (NR) Int4: −1.1 (NR) *P*=0.77

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Table 5. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline HbA_{1c}, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: HbA_{1c} (% or % Change)
	HbA_{1c} (%), M (SD): Int1: 9.4 (1.7) Int2: 9.3 (1.6) Int3: 9.2 (1.4) Int4: 9.2 (1.6) Retention: 70%			Intervention adherence: Attendance (4/6 sessions): Int1: 75.6% Int3: 72.7% No. of entries/y: Int2: 342 Int3: 359 Interventionist: Int1: NR Int2: NR Int3: NR Int4: NR	
Systematic reviews and meta-analyses					
Liang et al,[173] 2011 Design: Meta-analysis of 22 clinical trials Outcome: Δ in HbA_{1c} (%)	N=1657 Mean age (SD): 44 (18) y Women: 45% White: NR	Studies on impact of mobile phone intervention on diabetes self-management	SMS to deliver blood glucose test results and self-management information	Duration: median, 6 mo (range, 3–12 mo)	Median 6 mo pooled Δ in HbA_{1c} (%), M (95% CI): −0.5 (−0.3 to −0.7), indicating that the reduction of HbA_{1c} value was 0.5% lower in mobile Int groups compared with other Int groups Subgroup analysis showed greater Δ in HbA_{1c} in type 2 than type 1 diabetes mellitus (−0.8% vs −0.3%) *P*=0.02
Pal et al,[174] 2013 Design: meta-analysis of data from 11 Trials Outcome: HbA_{1c} (%)	N=3578 Mean age: 46–67 y Time since diagnosis: 6–13 y	Assess the effects on health status and health-related quality of life of computer-based diabetes self-management interventions for adults with type 2 diabetes mellitus	Computer-based interventions	Duration: range, 1–12 mo	Based on 2637 Ps; 11 trials: Pooled effect on HbA_{1c}: 0.2% (95% CI, −0.4 to −0.1) *P*=0.009 Based on 280 Ps; 3 trials. The effect size on HbA_{1c} was larger in the mobile subgroup: mean difference in HbA_{1c}: −0.5% (95% CI, −0.7 to −0.3) *P*<0.00001

Automated indicates without a clinician who generates, tailors, or modifies the output; Baseline, 0; BP, blood pressure; CI, confidence interval; CO, coach only; Δ, change or difference; eMOD, electronic Management of Diabetes; HbA1c; hemoglobin A1c; Int, intervention group; ITT, intention to treat; M, mean; n, subgroups; N, total sample; NA, not applicable; NICHE, Novel Interactive Mobile-Phone Technology for Health Enhancement; NR, not reported; P, participant; PA, physical activity; PCP, primary care physician; PDA, personal digital assistant; RCT, randomized, controlled trial; SMBG, self-monitoring blood glucose; SMS, short message service; and UCDC, Ubiquitous Chronic Disease Care.

effects, and economic data.[174] A review of 11 studies by Pal et al[174] provided data for a meta-analysis from which the authors reported pooled results indicating a small, statistically significant difference in outcomes between the intervention and comparison groups (mean difference, −0.21; 95% confidence interval, −0.4 to −0.1). However, for 8 of the reviewed studies, they reported that the significant mean difference in the HbA_{1c} change for mHealth interventions compared with control condition ranged from 0.01 to −0.8 (95% confidence interval, −1.45 to 0.15).

An early review of evidence on barriers and drivers of the use of interactive consumer health information technology by the elderly, people with chronic conditions or disabilities, and the underserved concluded that questions remain as to the optimal frequency of use of systems by patients and providers and whether the success of interventions depends on repeated modification of the patient's treatment regimen or ongoing assistance with applying a static treatment plan.[179] A recent review focused on the effect of mobile phone interventions for

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glucose control in diabetes mellitus.[173] This meta-analysis of 22 studies with 1657 participants showed that mobile phone interventions significantly reduced HbA_{1c} by a mean of 6 mmol/mol or 0.5% over a median follow-up of 6 months. Among the studies that we reviewed (Table 5), duration of interventions in the studies varied from 3 to 18 months. However, it should be noted that most clinical trials we reviewed examined change in HbA_{1c} during a 3-month intervention, and very little was reported about the engagement and persistence of use with the technology. Participants randomized to the intervention arms of the trials received enhanced clinical attention and may have received diabetes mellitus management supplies. Therefore, it may be inaccurate to assume that a significant change in HbA_{1c} in an intervention group at 3 months is attributable to technology instead of other nonspecific benefits of participation, especially considering a report from a 2011 survey that showed that 26% of downloaded health apps are used only once and 74% are abandoned by the 10th use.[180]

The use of heterogeneous interventions (mobile phones, SMS, or Internet based) makes it more difficult to determine the effect of any single technology component on HbA_{1c}. As suggested in other reviews[174,181] of studies with different technology-based approaches (eg, automatic SMS messages versus personalized feedback), a single component of technology may affect different behaviors in ways not clearly distinguishable when intervention components are combined. Authors of 2 systematic reviews concluded that interventions were more likely to be successful if they selected and combined theory-based behavior change strategies,[174,182] including interactive components that involve tracking, personalized feedback, and peer support.

Gaps and Recommendations for Future Directions

Few studies focus on high-risk, underserved, or minority populations. Most studies do not report changes in antihyperglycemic medications during the intervention, which may affect the change in HbA_{1c}. Without that information, it is difficult to determine whether changes in lifestyle behavior or changes in medications contributed to the effectiveness of the mobile intervention. It is possible that reports of the follow-up secondary analyses of such studies have not been published or that our search missed them. The reviewed studies did not report intervention dose or receipt, that is, the number of SMS messages or push notifications sent and opened by participants. Only 1 study[170] reported differences in HbA_{1c} change as a function of different baseline HbA_{1c} levels, which may be important for understanding who will most benefit when specific populations, including older adults, are targeted. Similar to other sections in this statement, we recommend here that future studies address the need to identify specific behaviors that may impact glucose management singly or in combination.

We recommend the following:

- Technology development or intervention development should be considered to meet the needs of specific population groups: older adults with age-related changes such as vision or touch, minorities needing culturally sensitive intervention content or materials and approaches, and low-income adults who may have inconsistent access to mobile technologies and supplies to support diabetes mellitus management.
- Studies should evaluate technology-supported glucose management for periods >3 months to determine the sustainability of engagement and the long-term effects of mHealth interventions in maintaining behavior changes.
- Studies are needed that include clinical, technical, and behavioral factors that may influence the initial engagement and ongoing use of mHealth and its associated impact on outcomes.
- Future studies should examine other outcomes related to improved diabetes mellitus management such as quality of life and acceptability of mHealth devices.
- Finally, we recommend that future studies examine the relationships among use of mHealth interventions, HbA_{1c} change, and healthcare use and costs, including consumer and provider costs. As more public and private insurers reimburse for the cost of mHealth interventions, evaluation of claims data from these populations may add to our understanding of cost-effectiveness.

Using mHealth to Improve Hypertension Care

Hypertension is a highly prevalent chronic medical condition that is a major risk factor in CVD. The risk for CVD events such as stroke or myocardial infarction doubles for every 20–mm Hg increase in systolic BP (SBP) and 10–mm Hg increase in diastolic BP.[183] Best practices for treatment of hypertension include a combination of pharmacotherapy and preventive lifestyle counseling for exercise, healthful eating, and smoke-free living.[183] Despite widespread initiatives to treat hypertension and the availability of antihypertensive medications, <50% of people in the United States have controlled BP.[150] This is thought to be due largely to suboptimal adherence to self-care.[184]

Strategies to improve self-care and adherence have been explored. Face-to-face counseling has been shown to be associated with reductions of 3 to 8 mm Hg in SBP among patients with hypertension.[184] Team-based hypertension care, with partnership between a primary care physician and other professionals such as nurses, pharmacists, or community health workers, has been shown to increase the percentage of patients with controlled BP by 12%.[185] Still, costs of such care models prevent dissemination and sustainability.

The rapid growth of the Internet and mobile telecommunication offers unprecedented opportunity to improve patient access to and engagement with hypertension care.[186,187] In general, they follow the premise that patients might spend only a few hours a year with a physician or nurse, but they spend 5000 waking hours each year engaged in choices that affect their health.[188] These eHealth programs can be delivered by the Internet, e-mail, SMS, or similar electronic means to engage patients in remote BP, medication, and behavior monitoring and to provide patients relevant education, counseling and motivational support.

One example of an mHealth intervention that has become accepted as beneficial to the management of hypertension is self-measured BP (SMBP) monitoring. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure recommends SMBP monitoring as an adjunct method in the management of hypertension.[183] The AHA recommends SMBP for the evaluation of most patients with known or suspected

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hypertension to assess response to treatment and possibly to improve adherence.[189] Still, much remains unknown about what other mHealth interventions are effective in improving hypertension care.

Review of Evidence for the Efficacy of Mobile Technology–Based Interventions to Promote BP Control

Our review focuses on mHealth intervention effects on SBP specifically, given its association with cardiovascular outcomes. We searched PubMed for the years 2004 to 2014 using the following terms: *hypertension*; *hypertensive*; *antihypertensive*; *anti-hypertensive*; *pre-hypertensive*; *high blood pressure*; *elevated blood pressure*; *increased blood pressure*; *systolic blood pressure*; and *diastolic blood pressure*. These terms were cross-referenced with the mobile technology terms described previously. This search resulted in 316 identified articles; 191 were excluded because they were not relevant to mobile technologies. The remaining 125 were articles reporting descriptions of technology, pilot data, and surveys on physician or patient opinions; were editorials; or did not focus on BP. Of the 39 remaining, only 13 RCTs were of sufficient quality to be included in this review. These studies were published between 2008 and 2014 and permitted patients some form of electronic platform to assist with self-monitoring or support for hypertension (Table 6). We focused on interventions that offered some additional feature beyond simply SMBP monitoring, and we included Internet-based studies because an increasing number of people access the Internet on mobile devices.[26] We divided the review to describe first individual studies organized by the primary form of mHealth used to deliver the intervention and then existing systematic reviews. Here, we provide details on the salient studies and what was learned from the review.

Three RCTs used text messaging as the primary intervention modality.[192–194] The details of these studies are provided in Table 6. The 3 studies had methodological limitations including poor retention. Two of the studies[193,194] reported significant differences in BP reduction between the treatment conditions; however, all studies reported results using the completers' analysis approach rather than intention to treat.

E-mail was the primary intervention modality for 3 RCTs.[191,195, 202] These studies ranged from 4 to 6 months, and all had high retention. The frequency of the e-mail contact was not specified in the Nolan et al[195] study and was frequent in the other studies. Madsen et al[191] augmented the e-mail information exchange with messages sent via a PDA. Cicolini et al[202] and Nolan et al,[195] using a completers' analysis, reported a significant difference between groups in BP changes, whereas Madsen et al,[191] using intention-to-treat analysis, did not find a difference in BP between groups but observed that a significantly higher proportion of the intervention group achieved the target BP.

A single study was found that used IVR as the primary intervention modality and was conducted in Honduras and Mexico.[196] Participants received weekly information on medication adherence and salt intake tailored to their BP through the IVR. There was only a trend for a significant difference in BP reduction from the control group, which may be attributable to only 67% completion of the IVR calls.

Two RCTs used a Web site as the primary intervention modality.[197,201] Thiboutot et al[201] enrolled 500 adults from primary care practice offices in central Pennsylvania. The Web-based intervention provided feedback on reported BP and advice; however, only 35% of intervention participants used the Web site at least once monthly.[201] Watson et al enrolled 404 adults with high BP from 6 worksites for a 6-month study that included a Web site that displayed SMBP readings and provided education and custom messages based on BP reports.[197] Adherence to SMBP was low overall, with only 17% of intervention participants reporting SMBP in month 1 and 7% at month 6. Neither of these studies demonstrated significant reductions in BP, and no differences were seen between intervention and control conditions. It was not stated but it is possible that the adherence was so low because participants might not have had the capability to access the Web site via a mobile device.

Three RCTs used a mixture of mHealth modalities to deliver the intervention. Green et al[190] used Web access, including secure e-mail, medical records, a health library, and links to resources, versus a Web plus pharmacist or a control (usual care) condition. Only the Web plus pharmacist group reduced their SBPs significantly better than the other conditions at 12 months. That modality also resulted in increases in secure messaging between patient and provider/pharmacist and more antihypertensive medication classes being added. McKinstry et al[199] compared 6 months of SMBP with access to a Web site with graphical displays of SMBP data and optional automated SMS or e-mails with feedback on their BP control against a control condition. Adherence to uploading BP data was high, but the number of participants opting for SMS or e-mails was not reported. The mean reduction in SBP in the intervention group was significantly higher than in the control group. In addition, there were more outpatient care visits and antihypertensive medications prescribed in the intervention group. Magid et al[198] recruited patients from primary care clinics and randomized them to a control condition or an intervention using the Heart360 Web site (https://www.heart360.org/) to upload their SMBP, IVR reminders if patients did not enter BP data, and phone calls and e-mails from a pharmacist recommending antihypertensive pharmacotherapy changes. Although Magid et al used some components of mHealth in this intervention, it does not appear that the phone component was based on mobile devices. Adherence to uploading BP data was high, and there were higher rates of e-mails and phone calls with pharmacists in the intervention group. Results revealed a significant mean reduction in SBP in the intervention group at the end of the 6-month study. All 3 of these studies provided some combination of patient educational resources, timely delivery of BP data to providers, and personalized messages to patients. The positive results of the 3 trials may suggest that a combination of such strategies or modes of intervention delivery may be needed to engage patients. Whether these multimodal technology-based approaches can provide the same or better results than team-based in-person care for a lower cost remains unclear; the data at this time suggest that further investigations are warranted. What is clear from this review of studies targeting improved BP control and other sections that addressed interventions targeting behavior is that mHealth or digital health has no defined taxonomy or classification of interventions delivered by the existing technology. Thus, it is

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Table 6. Description of Studies Using mHealth for BP Control

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
Green et al,[190] 2008 Design: 3-group RCT Outcome: percent of Ps with BP <140/90 mm Hg Setting: 10 medical centers Country: United States	N=778 Int1: n=258 Int2: n=259 Int3: n=261 Mean age (SD): Int1: 59.5 (8.3) y Int2: 59.3 (8.6) y Int3: 58.6 y (8.5) y Mean SBP (SD) mm Hg: Int1: 152.2 (10.0) Int2: 152.2 (10.4) Int3: 151.3 (10.6) Women: Int1: 45.9% Int2: 55.9% Int3: 54.7% White: Int1: 86.1% Int2: 79.3% Int3: 82.9% Retention: Int1: 95.0% Int2: 90.8% Int3: 95.8%	Int1: Home BP monitoring, secure e-mail, refilling medications, viewing medical record, health library, links to resources Int2: Int1+2-wk pharmacist interaction via Web (action plan) and secure messaging Int3: Hypertension pamphlet	Home BPM equipment, Web site, secure messaging	Duration: 12 mo Contacts: Int1 and Int2: Office BP measurement at baseline and 12 mo Int3: Office BP measurement at baseline and 12 mo Intervention adherence: PCP visits: Int1: 2: 3.2 Int2: 1: 3.0 Int3: 3.2 Int1: 2..4 (4.6) Int2: Pharmacist messages: 22.3 (10.2) Int3: 3.3 (7.4) Int1: 3.8 (5.0) Int2: Pharmacist phone calls: 7.5 (9.3) Int3: 4.0 (4.8) Interventionist: Int1: Pharmacist Int2: Pharmacist Int3: NA	Completer's analysis (n=730) 12 mo: Achieved <140/90–mm Hg target: Int1: 36% Int2: 56% Int3: 31% *P*<0.001 Mean SBP Δ, mm Hg: Int1: −8.2 Int2: −14.2 Int3: −5.3 *P*<0.001
Madsen et al,[191] 2008 Design: 2-group RCT Primary outcome: Office-based SBP Setting: Primary care setting Country: Denmark	N=236 Int1: n=113 Int2: n=123 Mean age (SD): Int1: 55.0 (11.7) y Int2: 56.7 (11.6) y Mean SBP (SD) mm Hg: Int1: 153.1 (13.2) Int2: 152.2 (13.7) Women: Int1: 51.3% Int2: 48.0% White: NR Retention: Int1: 93% Int2: 96%	Int1: Ps self-monitored BP 3 times/wk for 3 mo, then 1 time/wk for 3 mo; transmission via secure Web site with Internet recommendations and PDA messages to P Int2: Informed about study but no active intervention	Home BP monitoring equipment, PDA, e-mails	Duration: 6 mo Contacts: Int1: Office BP measurement at baseline and 6 mo; continuous education and medication adjustment Int2: Office BP measurement at baseline and 6 mo Intervention adherence: No data on adherence to home BP monitoring Interventionist: Int1: General practitioner Int2: NA	Completer's analysis (n=223) 6 mo: Mean SBP Δ, mm Hg: Int1: −11.9 Int2: −9.6 *P*=NS Achieved BP target: Int1: 60% Int2: 38% *P*<0.001
Cottrell et al,[192] 2012 Design: Quasi-experimental (nonrandomized) Outcome: SBP Δ Setting: 10 general practitioner groups Country: United Kingdom	N=488 Int1: n=124 Int2: n=364 Mean age (range): Int1: 59 (25–86) y Int2: 60 (36–87) y	Int1: Ps self-monitoring BP. SMS results to a secure server. Reminders to check BP and recommendations to contact general practitioner were sent to Ps as SMS as needed. Results reviewed by general practitioner or nurse at least weekly	Secure server, SMS	Duration: Minimum, 3 mo or until BP controlled; maximum, 6 mo Contacts: Int1: Daily measurement of home BP with daily reminders if no BP value received Int2: BP abstracted from clinic chart	Completer's analysis Int1: n=89 Int2: n=NR 0–3 mo: Mean SBP Δ, mm Hg: Int1: −8 Int2: +1

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
	Mean SBP (range) mm Hg: Int1: 146 (82–194) Int2: 136 (87–197) Women: Int1: 40% Int2: 40% White: NR Retention: 41%	Int2: Informed about study but no active intervention		Intervention adherence: Continued 3–6 mo: 37 (30%) Completed 3 mo and stopped: 51 (41%) Interventionist: Int1: General practitioner or nurse Int2: NA	0–3 mo (Ps meeting criteria #2): Mean SBP Δ, mm Hg: Int1: −15.88 Int2: −11.42 *P*=NR
Kiselev et al,[193] 2012 Design: 2-group RCT (unblinded) Outcome: % P BP Setting: Single-center cardiology practice Country: Russia	N=199 Int1: n=97 Int2: n=102 Mean age (SD): Int1: 49 (11) y Int2: 51 (11) y Mean SBP (SD) mm Hg: Int1: 153.4 (9.6) Int2:158.2 (9.9) (*P*<0.05) Women: Int1: 45% Int2: 50% White: NR Retention: Int1: 64% Int2: NR	Int1: Ps self-monitoring BP and other values requested from server by SMS and Ps' responses submitted by SMS. If weekly average BP not at target, Ps invited via SMS or phone for office visit or telephone consultation. Int2: Standard-of-care drug therapy and lifestyle recommendations; Ps encouraged to check BP at home	Secure Internet-based Web site, SMS	Duration: 12 mo Contacts: Int1: SMS requests and reminders sent to Ps on a variable frequency (daily to semiannually) on factors related to BP control and medication adjustments. No minimum frequency of office visits. Int2: No reminders sent; frequency of office visits determined by physician; but must be at least every 6 mo Intervention adherence: Ps withdrawn if did not respond to SMS for 1 mo. Int1: 18 (51%) withdrew as a result of loss of interest, 12 (34%) as a result of technical difficulties, 5 (15%) for unknown reasons. Int2: NR Interventionist: Int1: Physician Int2: Physician	Completer's analysis (n=164) 12 mo: % Ps achieving BP goal: Int1: 77% Int2: 12% *P*<0.001 Mean SBP Δ, mm Hg: Int1: −23.7 Int2: −6.9 *P*=NR
Logan et al,[194] 2012 Design: 2-group pilot RCT Outcome: 7-d ambulatory SBP Setting: 5 general practitioner groups Country: Canada	N=110, Int1: n=55 Int2: n=55 Mean age (SD): Int1: 63.1 (9.0) y Int2: 62.7 (7.8) y Mean SBP (SD) mm Hg: Int1: 142.6 (10.2) Int2: 142.7 (10.9) Women: Int1: 38% Int2: 51% White: Int1: 71% Int2: 60%	Int1+self-care: Messages tailored to BP reading. Alerts to provider on abnormal SBP; automated voice messages when nonadherent to BP readings; printouts of summary BP to doctors. Interventionist: Physician Int2: Home BP monitor, measure 2 times/wk in morning and 2 times/wk in evening	Bluetooth, Blackberry smartphone software, home BP monitor	Duration: 1 y Contacts: Int1: Average alerts to Ps, 1.82 (3.69); alerts to doctors, 0.09 (0.35) Int2: Only at assessments, Office BP measurement at baseline and 1 y Intervention adherence: Readings per week: 10.8 (6.7) Decline in percent adherent per week: −1.8	Completer's analysis (n=105) 12 mo: SBP Δ, mm Hg, Mean (SD): Int1: −9.1 (15.6) Int2: −1.5 (12.2) *P*<0.005 Achieved <130/80 target: Int1: 51% Int2: 31% *P*<0.05

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
	Retention: Int1: 96.4% Int2: 92.8%			Interventionist: Int1: Primary care physician Int2: Primary care physician	
Nolan et al,[195] 2012 Design: RCT Outcome: SBP Δ Setting: 3 sites Country: Canada	N=387 Randomized: Int: n=194 Control: n=193 Actual exposure (analyzed sample): Int1: n=97 Int2: n=63 Int3: n=227 Mean age (95% CI): Int1: 55.7 (54.3–57.0) y Int2: 57.0 (55.2–58.8) y Int3: 56.7 (55.7–57.7) y Mean SBP mm Hg: Int1: 143.3 Int2: 134.6 Int3: 139.6 Women: Int1: 72.2% Int2: 61.9% Int3: 52.9% White: NR Retention: Int1: 76.8% Int2: 81.9%	Int1: E-counseling on recommendations for diet, exercise, smoke-free living based on stage of change (≥8 e-mails over 4 mo) Int2: Received Heartline e-newsletters from the Heart and Stroke Foundation that contained general information and advice for heart-healthy living	E-mail	Duration: 4 mo Contacts: Int1: Month 1: Weekly e-mails Month 2: Bi- weekly e-mails Months 3 and 4: Monthly e-mails Intervention adherence: BP readings: Month 1: 17% Month 6: 7% Interventionist: Int1: NR Int2: NR	ITT analysis: no significant difference between groups on Δ in primary outcomes. Per-protocol analysis was conducted with 3 groups according to whether Ps received ≥8, 1–7, or 0 e-mails (control) 4 mo: Mean SBP Δ, mm Hg: Int1: −8.9 (−11.5 to −6.4) Int2: −5.8 (−9.1 to −2.6) Int3: −5.0 (−6.7 to −3.3) *P*=0.03 (Int1 vs Int3)
Piette et al,[196] 2012 Design: 2-group RCT Outcome: SBP Setting: 8 clinics Country: Honduras and Mexico	N=200: Int1: n=99 Int2: n=101 Mean age (SD): Int1: 58.0 (1.3) y Int2: 57.1 (1.1) y Mean initial SBP (SD) mm Hg: Int1: 153.2 (2.1) Int2: 150.0 (2.0) Women: Int1: 66.3% Int2: 68.4% White: NR Retention: Int1: 90% Int2: 91.1%	Int1: BP readings; automated feedback through IVR (medication adherence, salt intake, BP checks), e-mail alerts for health workers, elect to enroll family/ friend to get summaries of P status and support messages Int2: Usual primary care	Electronic home BP monitor, IVR, e-mails to providers	Duration: 6 wk Intervention contacts with clinicians: unmeasured Office BP measurement at baseline and 6 wk: Int1 adherence: 67% completed phone calls, 20% received call from clinician as a result of automatic e-mails Interventionist: Int1: Automated phone calls Int2: NR	Completer's analysis (n=181) 6 wk: SBP Δ mm Hg, Mean (SD): Int1: −10.7 (2.3) Int2: −6.4 (2.4) *P*<0.09 Achieved BP target: Int1: 57% Int2: 38% *P*<0.001
Watson et al,[197] 2012 Design: Cluster RCT Outcome: SBP Δ Setting: 6 worksites Country: United States	N=404 Int1: n=197 Int2: n =207 Sites: Int1: 3 Int2: 3	Int1: Ps self-monitoring BP, automatically transmitted data to a central server. Data were displayed on a self-management Web site. Ps logged onto the Web site ≥1 times/wk.	Home BPM, modem, Web site	Duration: 6 mo Contacts: NR Intervention adherence: BP readings: Month 1: 17% Month 6: 7%	ITT (how to handle missing data NR) 6 mo: Achieved SBP target: Int1: 21.3% Int2: 16.4% *P*=0.04

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
	Mean age (SD): Int1: 49.5 (8.0) y Int2: 48.4 (8.0) y Mean SBP (SD) mm Hg: Int1: 134 (14) Int2: 132 (14) Women: Int1: 21.3% Int2: 25.1% White: Int1: 86% Int2: 87% Retention: Int1: 95.4% Int2: 98.5%	The Web site allowed Ps to track BP, access educational material, and receive automated, tailored messages. Int2: Ps received training of BP self-monitoring but did not receive any feedback.		Interventionist: Int1: Automated messages Int2: NA	Mean SBP Δ, mm Hg: 0.49 *P*=0.8
Magid et al,[198] 2013 Design: 2-group RCT Outcome: proportion Ps achieved goal BP Setting: 10 Kaiser Permanente clinics Country: United States	N=348 Int1: n=175 Int2: n=173 Mean age (SD): Int1: 60 (11.3) y Int2: 59.1 (10.9) y Mean SBP (SD) mm Hg Int1: 148.8 (16.2) Int2: 145.5 (14.5) Women: 40% White: 83% Retention: Int1: 93% Int2: 95%	Int1: Provided home BP cuff, enrolled in Heart360 Web program, met with clinical pharmacy specialist for medication adjustment, provided lifestyle counseling. Both groups received written educational materials on managing BP, diet, PA; instructed to follow up with PCP.	Web-enabled software for home BP monitoring (Heart360)	Duration: 6 mo Contacts: Int1: Ps self-measure BP 3 times/wk, uploaded values into Heart360 Web site. Pharmacist made medication adjustments via telephone or secure e-mail to S and to PCP via EMR. Reminders for BP upload automated phone call. Intervention adherence: Median time to follow-up: 182 d in both groups. Int1 group: 70% Ps adherent (uploading values at least once a week >80% of study duration) Clinic visits, n (%): Int1: 3.3 (2.5) Int2: 3.1 (2.3) Telephone contacts: Int1: 5.3 (4.5) Int2: 3.5 (3.8) E-mail contacts: Int1: 6.0 (5.5) Int2: 2.4 (3.2) Interventionist: Int1: Clinical pharmacy specialist Int2: PCP	Completer's analysis (n=326) 6 mo: Achieved SBP goal: Int1: 54.1% Int2: 35.4% Adjusted risk ratio 1.5 (95% CI, 1.2–1.9) Mean SBP Δ, mm Hg: Int1: −20.7 Int2: −8.2 *P*=NR
McKinstry et al,[199] 2013 Design: 2-group RCT Outcome: SBP Δ Setting: 20 primary care practices Country: Scotland	N=401 Int1: n=200 Int2: n=201 Mean age (SD): Int1: 60 (11.3) y Int2: 59.1 (10.9) y Mean SBP (SD) mm Hg: Int1: 148.8 (16.2) Int2: 145.5 (14.5)	Int1: Self-monitor BP initially twice in morning, once in evening for first week and then weekly; used Bluetooth-enabled BP cuff with automated responses based on BP control and healthcare team review and recommendations Int2: Standard-of-care BP management	Electronic home BP monitor sent BP reading via Bluetooth to cellular, then transmitted via SMS to secure Web site	Duration: 6 mo Contacts: Int1: Automated response to patient based on BP control every 10 readings or weekly; healthcare team review at least weekly	Completer's analysis (n=359) 6 mo: Mean SBP Δ, mm Hg: Int1: −6.0 Int2: −2.2 *P*=0.0002

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
	Women: Int1: 38.3% Int2: 41% White: NR Retention: Int1: 97.5% Int2: 98.5%			Mean PCP visits (SD): Int1: 3.66 (2.67) Int2: 2.6 (2.52) (*P* for Δ between groups=0.0002) Intervention adherence: Compliance with BP checks in Int: Median of 76 BP readings; 89% of Ps completed >90% of expected minimum No. of readings. Interventionist: Automated messages, medication changes by physician Int2: Doctor or practice nurse	
Rifkin et al,[200] 2013 Design: 2-group RCT (2:1 ratio) Outcome: SBP Δ Setting: VA, CKD, and hypertension clinic Country: United States	N=43 Int1: n=28 Int2: n=15 Mean age (SD): Int1: 68.5 (7.5) y Int2: 67.9 (8.4) y Mean daytime ambulatory SBP (SD) mm Hg: Int1: 149 (16.2) Int2: 147 (8.6) Women: Int1: 7% Int2: 0% White: Int1: 75% Int2: 73% Retention: Int1: 93.3% Int2: 88.2%	Int1: Self-monitor BP using Bluetooth-enabled BP monitor, weekly phone calls for out-of-range BP readings (pharmacist counseling) Int2: Home BP monitoring, standard-of-care BP management	Electronic home BP monitor; home health hub (Bluetooth, Internet), secure Web site to view BPs	Duration: 6 mo Contacts: Int1: 2.7 over 6 mo; 1.9 medication changes per patient Intervention adherence: 29 readings/mo; 78% of Ps used cuff 4 times/mo for 6 mo Int2: 20% brought BP records to medication visit Interventionist: Int1: Physicians and pharmacist Int2: Physicians	Completer's analysis (n=43) 6 mo: Mean SBP Δ, mm Hg: Int1: −13 Int2: −8.5 *P*=0.32
Thiboutot et al,[201] 2013 Design: Cluster RCT Outcome: SBP Δ Setting: 54 physician practices Country: United States	N=500 Int1: n=282 Int2: n =218 Sites: Int1: 27 Int2: 27 Mean age (SD): Int1: 59.6 (12.1) y Int2: 61.6 (11.4) y Mean SBP (SD) mm Hg: Int1: 132.7 (14.9) Int2: 132.4 (15.2)	Int1: Automated Web site with tailored messages based on self-report BP; suggestions for questions to ask PCP Int2: Web site with general prevention service information unrelated to hypertension care	Internet Web site	Duration: 12 mo Contacts: Int1 and Int2: Office visits at baseline, 12 mo Intervention adherence: 34.8% used Web site ≥1 time each of 12 mo; 82.2% used Web site at least once. Interventionist: Int1: Automated messages Int2: NA	ITT (LMM) 12 mo: Achieved target: Int1: 71.3% Int2: 65.6% *P*=0.31 Mean SBP Δ, mm Hg: Int1: −4.4 Int2: −3.5 *P*=0.88

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
	Women: Int1: 58.5% Int2: 56.4% White: Int1: 75.5% Int2: 74.3% Retention: Int1: 84% Int2: 83%				
Cicolini et al,[202] 2014 Design: 2-group RCT (unblinded) Outcome: SBP Δ Setting: Single-center hypertension primary care Center Country: Italy	N=203 Int1: n=102 Int2: n=101 Mean age (SD): Int1: 59.8 (15) y Int2: 58.3 (13.9) y Mean SBP (SD) mm Hg: Int1: 150 (11) Int2: 153 (12) (*P*=0.12) Women: Int1: 50% Int2: 48% White: NR Retention: Int1: 98% Int2: 97%	Int1: 1-h education program on risk factors and healthy lifestyle plus weekly e-mail alerts and phone calls from a nurse care manager Int2: 1-h education program on risk factors and healthy lifestyle	E-mail reminders	Duration: 6 mo Contacts: Int1: Weekly e-mail reminders Both groups: follow-up visits at 1, 3, and 6 mo Daily self-assessment form of adherence to treatment. Intervention adherence: Mean PCP visits (SD): Int1: 3.66 (2.67) Int2: 2.6 (2.52) (*P*=0.0002 for Δ between groups) Compliance with therapy dose (%): Int1: 100 Int2: 96.9 Compliance with therapy hours: Int1: 91% Int2: 96.9% Interventionist: Int1: Nurse care manager Int2: Nurse care manager	Completer's analysis (n=198) 6 mo: Mean SBP Δ, mm Hg: Int1: −14.9 (8.1) Int2: −10 (11.6) *P*<0 .001
Systematic reviews and meta-analysis					
Uhlig et al,[203] 2013 Design: Systematic review and meta-analysis Outcome: SBPΔ Setting: no setting restrictions Country: no language restrictions	Prospective comparison studies with at least 8 wk follow-up. Analysis 1: SMBP+support vs usual care; 25 studies Analysis 2: SMBP+support vs SMBP; 13 studies	Support included educational materials, letters to Ps and providers on treatment recommendations, Web resources, phone monitoring with electronic transmission of BP data, telecounseling, behavioral management, medication management with decision support, nurse or pharmacist visits, calendar pill packs, and adherence contracts	Only 1 study used Web-based pharmacist counseling	Analysis 1: 5 quality A studies Analysis 2: too heterogeneous Intervention adherence: NR Study duration: 8 wk	Analysis 1: 12 mo: Mean SBP Δ: −2.1 to 8.3 mm Hg Analysis 2: NR

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Table 6. Continued

Study Cited, Design, Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline BP, Study Retention	Study Groups and Components	Technology Used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Primary Outcome: Mean SBP (mm Hg or % Change)
Liu et al,[204] 2013 Design: Systematic review and meta-analysis Outcome: SBP Δ Setting: no setting restrictions Country: no language restrictions (56% in United States)	Prospective comparison studies testing preventive e-counseling or advice using Web sites or e-mails to modify exercise or diet as a means of improving blood pressure control of at least 8-wk duration. 13 studies: N=2221 Mean age: 55 (range, 18–89) y Mean SBP (SD) mm Hg: 136 (6.4) Women: 44% White: NR Retention: 53%–94%	E-counseling or advice using Web sites or e-mails to modify exercise or diet as a means of improving BP control	Internet, e-mail The Internet-based interventions were primarily self-guided, access was through desktop and mobile devices	Mean intervention duration (SD): 5.6 (3.6) mo 8 of the 13 studies were short term (<6 mo), 5 were long term (6–12 mo) Intervention adherence: NR	Pooled: Mean SBP Δ, mm Hg: Int: −3.8 (95% CI, −5.63 to −2.06) Pooled effect size: −0.27 (95% CI, −0.4 to −0.1) Longer interventions vs shorter interventions, effect size on SBP: −0.44 (95% CI, −0.58 to −0.31) vs −0.23 (95% CI, −0.36 to −0.10) ≥5 vs <5 behavioral change techniques effect size on SBP: −0.46 (95% CI, −0.60 to −0.33) vs −0.19 (95% CI, −0.33 to −0.06)

Automated indicates without a clinician who generates, tailors, or modifies the output; baseline, 0; BP, blood pressure; BPM, blood pressure monitoring; CI, confidence interval; CKD, chronic kidney disease; Δ, change or difference; EMR, electronic medical record; Int, intervention group; ITT, intention to treat; IVR, interactive voice response; LMM, linear mixed model; M, mean; n, subgroups; N, total sample; NA, not applicable; NR, not reported; NS, not significant; P, participant; PCP, primary care physician; PDA, personal digital assistant; RCT, randomized, controlled trial; SBP, systolic blood pressure; SD, standard deviation; SMS, short message service; and VA, Veterans Affairs.

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difficult to summarize the study outcomes by such a classification of interventions. The current state of science suggests that all options all have an important place in targeting improved cardiovascular health.

In summary, 8 of the 12 studies detailed in Table 6 were conducted outside the United States, and 2 of those were conducted in Canada, so results may not be generalizable to all healthcare systems. Most but not all studies used self-monitoring of BP and used those data for reporting and receiving feedback. Eight of the studies reported a significant difference between the treatment conditions, but only 3 of the 12 studies used an intention-to-treat approach in analyzing the results. Instead, most studies reported results only in experimental subjects who were compliant with the mHealth technology used. This approach not only inflates the results and compromises randomization but also raises questions about the generalizability to a broad hypertensive population, particularly elderly or disabled patients such as those with stroke who may have difficulty using the technology.

We identified 2 systematic reviews and meta-analyses examining studies testing mHealth interventions for BP control.[203,204] Using the same quality assessment tool for systematic reviews and meta-analyses as in the AHA/ACC guideline, both systematic review studies were rated good quality (indicating a study with the least level of bias and results deemed valid). Both reviews focused on a slightly different topic but shared common features. Uhlig et al[203] focused on SMBP monitoring with or without additional support, and Liu et al[204] focused on Internet-based interventions for BP control. Both reviews suffered from heterogeneity across studies in SMBP equipment used, intervention modality and components, participants, and BP end points, precluding direct comparisons across studies. Neither of the systematic reviews exclusively included RCTs. Both reviews focused on intervention comparison with usual care or no intervention, whereas only Uhlig et al examined comparison with an active control (SMBP self-monitoring), and only Liu et al attempted to determine which of the intervention characteristics were associated with better outcomes.

Uhlig et al[203] reviewed 25 studies that compared SMBP plus support with usual care. Among the 5 quality A studies that compared SMBP plus support with usual care, there was a net reduction in SBP of −2.1 to −8.3 mm Hg. The type of support offered varied greatly across studies, and only 1 study used an mHealth support intervention.[190] Uhlig et al also examined 13 trials comparing SMBP with SMBP plus support and found no evidence to support the benefit of SMBP plus support over SMBP alone. Liu et al[204] examined 13 studies that compared Internet-based counseling interventions on BP control in prehypertensive and hypertensive patients, 11 of which were RCTs. They found that e-counseling interventions significantly reduced daytime SBP by 3.8 mm Hg (95% confidence interval, −5.63 to −2.06). They also found that longer interventions (6–12 months) were associated with greater effects on SBP. Additionally, Liu et al also found trends of greater effects when interventions used multiple behavioral techniques and were proactive with patients (as opposed to reactive or passive). Nolan et al[195] conducted the 1 study to specifically explicate a theoretical framework.

A significant limitation of the current evidence for the use of mHealth for BP control is that the majority of studies (8 of

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12) were conducted for ≤6 months, with no studies extending beyond 12 months. Given that hypertension is a chronic condition that requires long-term medical care, a sustained benefit of mHealth interventions beyond a few months should be demonstrated before this technology becomes widely accepted. Although adherence to some mHealth technologies over the short term may have been demonstrated, the ability to maintain the consumers' interest and active use of these tools over the long term requires further study.

Gaps and Limitations

The results of the studies described above indicate that mHealth interventions in general show promise in reducing SBP in patients with hypertension but with large variability in behavioral targets, intervention components, delivery modalities, and patient engagement. Although behavioral targets for BP control include routine monitoring of BP, healthful dietary intake, physical activity, medication adherence, smoking cessation, and stress management, among others, existing mHealth interventions have not identified how best to address these behaviors. Questions remain about which behaviors need to be addressed to change BP and in whom, as well as whether to address behaviors at the same time or sequentially, scheduled or not scheduled.

Essential components of mHealth interventions to promote BP control also largely remain unknown but likely include behavioral techniques similar to those shown in in-person counseling interventions to be effective, including self-monitoring, goal setting, and problem solving. Evidence[205] suggests that education alone is not effective in changing behavior, and results from Liu et al[204] suggest that multiple techniques are likely to be more effective than fewer techniques. Other unknowns include whether mHealth intervention components should be proactive or reactive, expert driven (protocol driven, prescriptive messaging) or user driven (collaborative protocol with supportive messaging), and whether some specific behavioral theories are more useful than others to guide intervention components.

The modalities used to deliver mHealth interventions for BP control included Web-based, e-mail, SMS, and IVR interventions. The best modality may never be known, given the rapid pace of change in information and communication technologies. In addition, the best delivery modality may vary between individuals and within individuals, given their locations and settings. Individual consumer factors such as age, access to the Internet, and learning preferences may determine the successful use of specific tools in a specific individual. Therefore, consumer preference may ultimately determine the most effective method of delivery in an individual patient.

Patient engagement with mHealth for BP control remains limited by the fact that the majority of studies (8 of 12) were conducted for ≤6 months, with no studies extending beyond 12 months. Given that hypertension is a chronic condition that requires long-term medical care, a sustained benefit of mHealth interventions beyond a few months will likely be needed to show meaningful health benefits. In addition, estimates of patient engagement with mHealth interventions over these short periods were not possible because of the heterogeneity of studies reviewed and because the components useful to maintain engagement specifically were not studied.

Aside from these current scientific limitations and unknowns of how best to use mHealth interventions to improve BP control, the commercial availability of evidence-based mHealth interventions for patients and providers is scarce. For example, the only commercially available intervention of which we are aware is the Heart360 Web site (https://www.heart360.org/). However, the current use rates of such programs remain unknown, and consumer adherence outside monitored RCTs may be difficult to predict. Adoption of mHealth interventions for BP control in health systems may additionally be hindered by security and patient privacy policies concerning the transmission of identifiable patient data, nonexistent current reimbursement for eHealth interventions, and information technology interface difficulties.

Suggestions for Future Research

- Identify behavioral targets that are tailored to an individual that will have the greatest effect on BP control and, if multiple behaviors, how best to attempt to change those behaviors.
- Leverage existing knowledge of effective intervention components for BP control from in-person counseling-based studies and adapt them to mHealth platforms while using the unique aspects of mHealth platforms to innovate components.
- Use delivery modalities that are currently used by individuals, meet the needs of their various lifestyles and preferences, and work across mHealth platforms. This includes trials testing mHealth interventions from a broader consumer base (elderly, disabled, etc).
- Study techniques to optimize retaining patient engagement beyond 6 months, including strategies such as gamification and contingency management (incentivization).
- Conduct trials comparing mHealth strategies with effective yet possibly more costly in-person counseling interventions.

Use of mHealth in Management of Dyslipidemia

Dyslipidemia affects nearly 1 in 5 to 10 Americans.[206] Despite ready access of healthcare providers to evidence-based cholesterol management goals and potent, well-tolerated medical therapy, management of hyperlipidemia remains suboptimal.[207] A large body of evidence accumulated over the last 2 decades supports the link between dyslipidemia and atherosclerosis[208–210] and the clinical benefits of statin therapy in the treatment of lipoprotein abnormalities. This evidence provides the basis for a number of consensus-based guidelines[19,211–217] for optimizing lipid levels in adult and pediatric populations. However, despite the wide dissemination of these guidelines, hyperlipidemia remains prevalent and suboptimally treated in the United States.[218]

There are several reported potential barriers to the implementation of these evidence-based treatment guidelines in clinical practice, including provider and patient knowledge, attitudes, and behaviors; provider-patient communication issues; and system-based issues such as costs and the lack of organized systems of care around the recognition and treatment of hyperlipidemia.[219,220] Thus, a multimodal approach affecting providers, patients, provider-patient communication, and care delivery systems is likely needed to translate these guidelines into clinical practice and to maximize the use of mHealth technology.

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Other barriers may include the unknown cost of delivering mHealth interventions to achieve optimal lipid control.

In 2012, the US Department of Health and Human Services[124] proposed a challenge seeking new mobile technology applications to help consumers assess their heart health risk, identify places to measure their BP and cholesterol, and use the results to partner with their healthcare professional to develop a treatment plan to improve their heart health. The new app would be part of a broader education effort in support of the Million Hearts initiative,[221] a public-private effort of the US Department of Health and Human Services that targets the prevention of a million heart attacks and strokes through clinical and community prevention programs.[222] In response to this challenge, the Marshfield Clinic developed the HeartHealth Mobile app, which allows users to obtain a health risk assessment based on several individual health factors such as blood cholesterol and BP values.

Currently, the majority of tools available for information delivery, education, motivation, and self-monitoring in dyslipidemia are contained within more comprehensive materials targeting overall CVD risk reduction.[202,222–231] Some of these materials provide the basis for the development of CVD risk scores and Web-based score calculators that are available for patients and providers. For example, the Framingham Risk Score was developed from predictive equations based on >5000 men and women who were 30 to 74 years old at baseline and were followed up for cardiovascular events for 12 years.[232] This score is sex specific and incorporates information on age, BP, total cholesterol, low-density lipoprotein cholesterol, diabetes mellitus, and smoking as predictors of CHD.[233]

Recently a task force of the ACC and the AHA published a set of guidelines aimed at reducing CVD risk.[234] The purpose of the guidelines was to define provider practices that meet the needs of patients; however, these guidelines were not meant as a replacement for clinical judgment. Although the guidelines had a relatively limited scope and focused on selected critical questions, they were based on the highest-quality evidence available. The guidelines were derived from evidence accumulated from RCTs, meta-analyses, and observational studies that were evaluated for quality and were derived from pooled cohort equations. CVD was defined as coronary death or nonfatal myocardial infarction or fatal or nonfatal stroke. A CVD 10-year and lifetime risk calculator was devised that is sex specific and incorporates information on age, race, total cholesterol, high-density lipoprotein cholesterol, SBP, treatment for high BP, diabetes mellitus, and smoking. The risk estimates are based on data from multiple community-based populations and are applicable to black and non-Hispanic white men and women 40 to 79 years of age. In addition, estimates of lifetime risk for CVD are provided for adults 20 to 59 years of age and are expressed as the lifetime risk for CVD for a 50-year-old individual without CVD who has the risk factor values entered into the spreadsheet. A downloadable spreadsheet and Web-based risk calculator are available on the AHA Web site (http://www.heart.org/HEARTORG/Conditions/HeartAttack/HeartAttackToolsResources/Heart-Attack-Risk-Assessment_UCM_303944_Article.jsp).[235] Because the primary use of these lifetime risk estimates is to facilitate the discussion of risk reduction through lifestyle changes, it is felt that the imprecision introduced is small enough to justify proceeding with lifestyle change counseling informed by these results. The guidelines were derived from evidence accumulated from RCTs, meta-analyses, and observational studies that were evaluated for quality.[235]

Review of Evidence for the Efficacy of Mobile Technology–Based Interventions to Promote Management of Dyslipidemia

We searched PubMed for the years 2004 to 2014 using the terms *anticholesteremic*; *cholesterol inhibitor*; *cholesterol level*; *cholesterol lowering*; *dyslipidemia*; *elevated cholesterol*; *HDL cholesterol*; *high density lipoprotein*; *hypercholesterolaemia*; *hypercholesterolemia; hyper-triglyceride*; *LDL cholesterol*; *lipoprotein cholesterol*; *low density lipoprotein*; *total cholesterol*; *triglyceride*; and *high cholesterol*. We reviewed 24 articles in detail reporting on the use of mobile technology to manage dyslipidemia as one of the goals. The majority of studies evaluated usability, feasibility, efficacy, and adherence to cholesterol improvement programs using technology-based tools or strategies such as e-mail, text messaging, and Web sites. Of note, several studies aimed at reducing diabetes mellitus or hypertension complications also included lipids as a secondary outcome.[164,202,228,236–239] Of these, only 3 studies were of sufficient quality to include here. Because of the limited number of studies using mHealth as part of the intervention to target improved lipids, we included studies reporting lipid as a secondary outcome in Table 7. The study by Yoo et al[164] is also reported in the sections on diabetes mellitus.

Some of the existing publications were focused on design, rationale, and testing accuracy of tools with no lipid outcomes available at this time.[223,240–242] Others were focused on small studies with inconclusive results[226,236,243] or were pilot feasibility studies that did not provide adequate results.[228,230] Only 1 peer-reviewed publication[244] addressed the topic of consumer use of technology as stand-alone tools specifically for lipid disorders (Table 7). The vast majority of publications did not meet the criteria for inclusion in the tables because of the absence of a control group or because they did not include lipids as a primary outcome. However, there were a number of promising studies in this group of articles. In a quasi-experimental study, Park and Kim[231] showed that the use of a Web site and SMS improved total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides. Oncescu et al[242] described a device that works with a smartphone camera to measure cholesterol. This device, if accurate and easy to use, might hold promise as a technology to allow self-monitoring of serum cholesterol; this should be evaluated in future research. Studies reported in design articles by Chow et al[240] and Redfern et al[245] show promise in the future management of dyslipidemia. RCTs testing interventions that specifically target lipid reduction are needed because there are no existing studies in this area. One study that used electronically monitored medication blisters and a reminder system reported that total cholesterol improved, but the study ended early.[237] Supplying patients with smartphones with Bluetooth-enabled BP monitors, glucometers, and a Web site for tracking resulted in decreases in total cholesterol; however, these studies did not include a control group.[228,230]

Research has shown that education of consumers and self- management interventions can be beneficial for patients. Advances in information technology and consumer health-related mHealth are emerging as promising tools for

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Table 7. Description of Studies Using mHealth for Management of Lipids

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline Lipids, Study Retention	Study Groups and Components	Technology used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Secondary Outcome
Kang et al,[238] 2010 Design: 3-group RCT Outcome: reduction of diabetes mellitus risk factors Setting: Community Country: South Korea	N=125 Int1: n=25 Int2: n=25 Int3: n=75 Mean age (SD): Int1: 47.47 (5.79) y Int2: 45.61 (6.06) y Int3: 45.84 (5.17) y Mean total cholesterol (SD) mg/dL: Int1: 195.48 (31.12) Int2: 222.32 (31.59) Int3: 204.04 (32.10) Mean LDL (SD) mg/dL: Int1: 121.70 (34.62) Int2: 135.20 (31.91) Int3: 135.72 (31.39) Mean HDL (SD) mg/dL: Int1: (13.37) Int2: 44.64 (13.66) Int3: 49.87 (13.80) Retention: 98.4%	Int1: 1-y face-to-face counseling (5 times over 12 wk), 10 e-mails over 30 wk, repeat assessment at 2 y Int2: 2-y face-to-face counseling (5 times over 12 wk, 10 e-mails over 30 wk in year 1, repeated in year 2; repeat assessment at 2 y Int3: Provided general health information at baseline, repeat assessment at 2 y	E-mail messaging	Duration: 2 y Contacts: Int1: 15 intervention contacts Int2: 30 intervention contacts Intervention adherence: NR Interventionist: Int1: Trained staff Int2: Trained staff Int3: NA	Completer's analysis (n=123) 24 mo: Total cholesterol Δ, M (SD), mg/dL: Int1: −0.09 (27.42) Int2: −11.12 (19.56) Int3: 5.75 (25.61) Int1 vs Int2 $P>0.05$ Int1 vs Int3 $P>0.05$ Int2 vs Int3 $P<0.05$ LDL Δ, mg/dL, M (SD): Int1: −6.65 (21.99) Int2: −5.32 (26.64) Int3: −11.41 (26.90) Int1 vs Int2 $P>0.05$ Int1 vs Int3 $P>0.05$ Int2 vs Int3 $P>0.05$ HDL Δ, mg/dL, M (SD): Int1: −2.78 (5.79) Int2: −3.28 (10.08) Int3: 0.67 (8.25) Int1 vs Int2 $P>0.05$ Int1 vs Int3 $P>0.05$ Int2 vs Int3 $P<0.05$
Dekkers et al,[225] 2011 Design: 3-group RCT Outcome: reduction in CV risk factors (waist, skin fold, blood pressure, total cholesterol, aerobic fitness level, body weight, BMI) Setting: Workplace intervention Country: Netherlands	N=276 Int1: n=91 Int2: n=93 Int3: n=92 Mean age (SD): 44.0 (9.2) y Women: 30.80% Mean BMI (SD): 29.7 (3.1) kg/m^2 Total cholesterol: 4.9 (0.8) mmol/L Retention: Int1: 54%, Int2: 54%, Int3: 65%	Int1: Internet ALIFE@ Work, a distance-counseling lifestyle intervention program by phone Int2: Internet ALIFE@ Work, a distance-counseling lifestyle intervention program by Internet Int3: Usual care (self-help materials on overweight, PA, and healthful diet brochures)	Internet or mobile phone	Duration: 6 mo intervention, 2-y follow-up Contacts: Int1: Phone calls every 2 wk Int2: Self-paced Maximum, 10 counseling contacts during 6 mo Intervention adherence: Used modules: Int1: 93.2% Int2: 87.5% Counseled on all modules: Int1: 64% Int2: 17% Interventionist: Int1: Counselors (dieticians, PA specialists) Int2: Counselors (dieticians, PA specialists) Int3: NA	Completer's analysis (n=141) 24 mo: Total cholesterol Δ, mg/dL, M difference (95% CI): Int1 vs Int3: 0.0 (−0.3 to 0.3) Int2 vs Int3: −0.1 (−0.4 to 0.2)

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Table 7. Continued

Study Cited, Design, Primary Outcome, Setting, Country	Sample Characteristics, Group Size, Baseline Lipids, Study Retention	Study Groups and Components	Technology used	Intervention Duration, No. of Intervention Contacts, Intervention Adherence, Interventionist	Secondary Outcome
Yoo et al,[164] 2009 Design: 2-group RCT Outcome: HbA_{1c} (%) Setting: Community Country: South Korea	N=123 Int1: n=62 Int2: n=61 Mean age (SD): Int1: 57.0 (9.1) y Int2: 59.4 (8.4) y Women: 47.2% Mean BMI (SD): 25.6 kg/m^2 Mean total cholesterol (SD): 4.6 mmol/L Retention: Int1: 91% Int2: 89%	Int1: UCDC system using mobile phones and Web-based interaction. UCDC included device attached to mobile phone that transmitted blood glucose data. Ps received SMS reminder to check blood glucose and tips via SMS 3 times/d. Physicians could follow the Ps' data and send individualized messages as needed Int2: Usual care. Ps visited according to usual schedule and received usual care in the outpatient setting.	SMS and Internet	Duration: 3 mo Contacts: Int1: 2 alarms daily to remind Ps to measure blood glucose values and blood pressure and 1 alarm daily for weight. Additionally, each P received at least 3 SMSs daily Int2: Dependent on usual-care routine. Each P was seen at baseline and at 3 mo to collect anthropometric and laboratory data. Intervention adherence: Int1: Sent in glucose readings 1.84±0.31 times/d with a compliance rate of 92.2±15.4% Sent in blood pressure readings 1.72±0.32 times/d with a compliance rate of 86.0±16.2% Sent in weight measurements 0.87±0.20 times/d with a compliance rate of 87.4±20.1% Interventionist: Int1: Automated Int2: NR	Completer's analysis (n=111) Total cholesterol Δ, mmol/L, M: Int1: −0.5, $P<0.001$ Int2: 0.0, $P=0.882$ $P=0.011$ LDL cholesterol Δ, mmol/L, M: Int1: −0.4 $P<0.001$ Int2: −0.1, $P=0.628$ $P=0.025$

Automated indicates without a clinician who generates, tailors, or modifies the output; baseline, 0; BMI, body mass index; CI; confidence interval; Δ, change or difference; HbA_{1c}, hemoglobin A_{1c}; HDL, high-density cholesterol; Int, intervention group; LDL, low-density cholesterol; n, subgroups; N, total sample; NA, not applicable; NR, not reported; P, participant; PA, physical activity; RCT, randomized, controlled trial; SMS, short message service; and UCDC, Ubiquitous Chronic Disease Care.

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facilitating the management of dyslipidemia, for example, home lipid testing with a smartphone, educational smartphone apps, and Web portals for patients and providers. Although there is evidence suggesting some benefit to their use, the amount of evidence-based literature in this area remains surprisingly low.

Gaps and Recommendations for Future Directions

The paucity of well-controlled trials for the use of mHealth interventions specifically for lipid disorders is remarkable, considering the prevalence of dyslipidemia in the general population.

- High-quality adequately powered trials are required to evaluate the role of mHealth-based interventions in dyslipidemia. As a result of a lack of adequately tested tools, guidelines for use cannot be provided.
- A critical but inadequately researched area is how to engage patients and providers to initiate the use of mHealth devices in education, evaluation, self-monitoring, and self-management of dyslipidemia. This first step may lay the groundwork for the creation of treatment tools using mobile technology.
- Additional research is needed in how providers wish to approach the consumer about managing dyslipidemia. It is possible that other health-related apps such as mHealth apps focused on lifestyle behaviors and, as indicated in a previous section, tools for the self-management of diabetes mellitus could be used in this population.

Summary of Representation of the Studies Reviewed

Our review included a total of 69 studies that investigated the use of mobile technologies to reduce CVD risk behaviors, which included 10 RCTs targeting weight loss, 14 on increasing physical activity, 14 aiming to improve smoking cessation, 15 on blood glucose management, 13 on hypertension management, and only 3 targeting lipid management. The majority were RCTs. For completeness, we also included systematic reviews and meta-analyses in each topic

Table 8. Number of Apps Found in the iTunes and Google Play Stores

	Apple Store	Android
Weight loss	3881	250
Physical activity/exercise	72/6312	120/120
Smoking	732	250
Diabetes mellitus	1175	180
Hypertension/blood pressure	214/588	250/250
Cholesterol	265	120
Medication adherence	38	250

The search on these terms was conducted in April 2015.

area except dyslipidemia, for which none existed. Overall, the studies had samples that were mixed in ethnicity, with a large portion being comprised of whites, although 1 study on increasing physical activity and 1 study on diabetes mellitus had 100% black samples. Female subjects made up the majority of many samples; however, 1 study conducted in a Veterans Affairs setting had 93% male representation. The smoking cessation studies enrolled younger individuals, usually 18 to 45 years of age, compared with most other studies, which included participants up to 70 to 75 years of age. The geographic distribution was quite variable; weight loss studies were conducted in the United States, whereas studies focused on dyslipidemia were conducted outside the United States. Several studies focused on smoking cessation were conducted in Europe. Seven of the 15 RCTs in diabetes mellitus were done in South Korea, and 2 were conducted in Europe. Thus, our evidence base also has limitations related to general representation, resulting in limited knowledge on the effectiveness of augmenting traditional patient care with the use of mHealth-supported strategies in male, minority, or underserved populations and for specific risk behaviors (smoking) or conditions (diabetes mellitus) among US populations. Other limitations identified across the studies are the continued reliance on Internet-based or SMS interventions and the somewhat limited use of advances in mHealth strategies; however, this may be attributable to delays in publication. From a methodological perspective, several studies did not use intention to treat in their primary analysis and thus biased the results of their studies. Use of completer's analyses was most evident in the studies focused on physical activity, BP, and dyslipidemia. Finally, several studies in the areas outside weight loss used relatively brief interventions.

We conducted a search of the Google (Android) and iTunes (Apple) App Stores for the terms used in this article: *weight loss*, *physical activity/exercise*, *smoking*, *diabetes*, *hypertension/BP*, and *cholesterol* (Table 8). Because medication may be a component of the treatment, we also searched for meditation adherence. There was a wide range in the number of apps available. Weight loss led the groups with nearly 4000 apps for the iOS and 250 for the Android operating systems. A search for physical activity yielded 72 apps, whereas exercise yielded 6312 apps for the iOS operating system and only 120 for both terms for the Android operating system. Cholesterol yielded the lowest numbers of apps for both operating systems. This wide array of apps included information delivery, education, motivation, self-monitoring, lifestyle, drug therapies, reminders or alerts, and alternative therapies. However, although the number of apps continues to grow at an exponential rate, none have been critically evaluated, and their development was not evidence based, often not building on the theoretical frameworks that address behavior change.[31,32,124,246–248] Besides lacking efficacy data, there is almost an absence of data on sustainability of engagement by the individual and thus sustainability of the treatment effect, an issue that is extremely important in managing chronic conditions such as hypertension. The absence of an empirical base for these apps is a major deficit in this potential area of prevention of CVD. Two recent articles addressed these issues and called for more informed use of the health-related apps and more rigorous approaches to developing and evaluating those that affect medical management (eg, diabetes mellitus, hypertension).[249,250]

These limitations beg for some innovative changes in intervention studies using mHealth. First, a more rigorous approach to the analytic methods used is needed. Second, more diverse samples from an ethnic, socioeconomic, and sex perspective should be included. Third, longer-term studies are needed that inform about the sustainability of effects of using mHealth approaches and the numerous apps to augment intervention and to assess the long-term engagement by the user. Finally, we need to use more adaptive and diverse methods in the testing of the rapidly changing mHealth devices and strategies and use approaches that can optimize the intervention designs and provision of efficacy data in a period shorter than the conventional 5-year RCT.[251–253] Identifying the most effective features in a shorter time frame also will reduce costs and ensure the incorporation of the most effective components early in the development phase.

How mHealth Tools Can Improve Healthcare Delivery When Partnered With Healthcare Providers

It is well established that a significant proportion of the CVD burden is preventable. Compared with pharmacological treatments for acute events and with secondary prevention, reductions in the prevalence of CVD risk factors have resulted in greater reductions in CVD-related mortality.[254] However, the amount of information that must be conveyed and the support that is necessary to counsel and motivate individuals to engage in behaviors to prevent CVD are far beyond what can be accomplished in the context of face-to-face clinical consultations or through traditional channels such as patient education leaflets.[255] mHealth or mobile technologies have the potential to overcome these limitations and to transform the delivery of health-related messages and ongoing interventions targeting behavior change. Moreover, the use of monitoring devices (eg, Bluetooth-enabled BP monitors and blood glucose monitors) permits the sharing of important patient self-management parameters with healthcare providers in real time and the delivery of feedback and guidance to patients when they need it. Furthermore, using mHealth tools for monitoring provides the clinician data that far exceed what can be measured in the brief clinical encounter and reflect the status of physiological or behavioral measures in the person's natural setting.

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Recommendations for Future Research

The development of drug and device therapies typically follows a standard path: Molecules that show promise in preclinical laboratory and animal testing are then evaluated in phase 1 human studies that provide an initial assessment of the safety of the agent. Those that survive phase 1 evaluation go on to larger phase 2 and 3 clinical trials in which the impact of the therapy is evaluated in progressively larger populations. Only those that are found to be clearly efficacious and safe in these rigorous evaluations are then eligible for regulatory approval and release to the general population. Even once on market, drugs and devices often undergo further monitoring to ensure that the findings seen in controlled trials are consistent with those seen in broader, more diverse patient populations and community settings.

In contrast, mHealth applications are often developed in the course of weeks to months as opposed to years for drugs. Once developed, mHealth applications have traditionally not been regulated by governmental agencies. Thus, these health apps may be offered to the public with limited to no information on the accuracy of their content; on whether they are based on proven learning theory or behavioral interventional strategies; or on whether they have undergone formal effectiveness and safety evaluation. While one may suggest that mHealth technologies do not require such careful scrutiny, there are arguments for such investigation. First, just like drugs or medical devices, these mobile technologies and applications have the potential to improve health, to be ineffective, or even to cause unanticipated harm. Second, without rigorous evidence to support them, it becomes difficult or impossible for care guidelines to recommend them or for clinicians to promote them. Third, the market is rapidly being flooded with these applications. Without evidence supporting the comparative usefulness of these apps, it is nearly impossible for the consumer (or clinician) to decide which to use. Finally, if a consumer who is motivated to modify his or her lifestyle selects an unhelpful product because of a lack of information, there is a true lost opportunity and a missed chance to improve health.

Specific sections above reviewed current mobile applications and technologies for treating obesity; encouraging regular physical activity, smoking cessation, control of hypertension, and dyslipidemia; and treating diabetes mellitus. Our literature searches uncovered a wide variety of products that have been developed. However, the reviews also identified the paucity of published empirical evaluation of their effectiveness. To date, many devices have no published evaluation, and those that have undergone evaluation are often limited to measuring customer satisfaction and user sustained engagement. Although such intermediate measures are important, they fall far short of actually determining whether the users of these products had clinically meaningful changes in biological parameters.

Several common themes were noted among each reviewed area. There were consistent concerns voiced about the designs of evaluative studies of mobile technologies. Studies often used a pre-post design without concurrent control groups or, better yet, randomized comparison groups. Without such controls, product effectiveness is likely to be overestimated. Similarly, many studies relied on self-report, which again leads to overestimation of effectiveness in unblinded evaluations. Additionally, many trials elected not to use an intention-to-treat perspective, which again may inflate the benefits of the intervention among those who used and stuck with the product.

To date, mobile technologies have generally been evaluated in motivated individuals and selected settings. These idealized conditions also will lead to exaggerations of the typical effectiveness that might be seen had the product been evaluated in general community practice or among diverse or underserved populations. Most studies were also of short duration, resulting in lingering questions about the sustainability or "stickiness" of the products. In particular, the fields of obesity and physical activity interventions are littered with interventions that work over the short term but fail to support durable lifestyle change. Perhaps most challenging, studies to date have almost uniformly evaluated a single technology compared with standard care, and there have been almost no head-to-head studies comparing various technologies with each another.

Beyond consistent questions about product safety and effectiveness, our review of the field found almost no studies that analyzed how products worked or user input in its development. Specifically, formative work had not defined which components in an intervention are pivotal to success or whether the impact of the product varies depending on the mode of use or delivery. Without these data, it is difficult to anticipate whether a similar but slightly different mobile technology would also be likely to be effective. Finally, these reviews pointed out the need for more implementation studies evaluating how to best incorporate these technologies (once proven) into a broader collaborative model of care.

Until such information is available, mobile app developers will continue to face questions and doubts from the public, providers, and payers. As with any other product that claims to improve health, groups will want to answers to certain questions: Does the product work best when used in certain settings or among specific patient groups? Does the app duplicate or potentiate impact when it is combined with other traditional interventions (such as in-person counseling)? If a specific mobile technology is found to be effective, in what cases can these findings be generalized among similar technologies in the class? Are the effects seen durable, or does the impact of the intervention wane over time? Finally, are there any unintended consequences associated with the device and program in which it is used?

Producing this evidence must be a shared responsibility. In the future, manufacturers will likely come under increasing pressure from regulatory agencies to produce evidence of effectiveness before marketing. Insurers are also likely to demand proof of durable effectiveness before they are willing to cover these services. However, the responsibility for generating evidence should not fall solely only on the product developers. The research and clinical communities also must help to generate these needed data. Our review of the evidence to date, even with its flaws and limitations, clearly demonstrates the great potential that mobile technologies can have to aid in lifestyle modification. Thus, clinicians should

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not conclude that mobile technologies are generally unproven and thus can be ignored. The current absence of evidence should not be used as evidence of an absence of effectiveness. Instead, we need to embrace the challenge of producing this needed evidence on how effective these new technologies are and how we can best adopt them in our practice to promote better patient health.

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*Modest.

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References

1. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF, Arnett DK, Fonarow GC, Ho PM, Lauer MS, Masoudi FA, Robertson RM, Roger V, Schwamm LH, Sorlie P, Yancy CW, Rosamond WD; American Heart Association Strategic Planning Task Force and Statistics Committee. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's Strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121:586–613. doi: 10.1161/CIRCULATIONAHA.109.192703.
2. Karmali KN, Lloyd-Jones DM. Achieving and maintaining cardiovascular health across the lifespan. *Curr Epidemiol Rep*. 2014;1:75–81. doi: 10.1007/s40471-014-0011-7.
3. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Judd SE, Kissela BM, Lackland DT, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Matchar DB, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Willey JZ, Woo D, Yeh RW, Turner MB; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2015 update: a report from the American Heart Association [published correction appears in *Circulation*. 2015;131:e535]. *Circulation*. 2015;131:e29–e322. doi: 10.1161/CIR.0000000000000152.
4. Eng TR. *The eHealth Landscape: A Terrain Map of Emerging Information and Communication Technologies in Health and Health Care*. Princeton, NJ: Robert Wood Johnson Foundation; 2001.
5. Akter S, D'Ambra J, Ray P. Trustworthiness in mHealth information services: an assessment of a hierarchical model with mediating and moderating effects using partial least squares (PLS). *J Am Soc Inf Sci Technol*. 2011;62:100–116.
6. Gagg C. *A Corpus Linguistics Study of SMS Text Messaging* [thesis]. Birmingham, UK: Department of English, University of Birmingham; 2009.
7. Hsu C-L, Lu H-P, Hsu H-H. Adoption of the mobile Internet: an empirical study of multimedia message service (MMS). *Omega*. 2007;35:715–726.
8. TechTerms.com. App. http://techterms.com/definition/app. Accessed April 14, 2015.
9. Merriam-Webster. Wireless. http://www.learnersdictionary.com/definition/wireless. Accessed April 17, 2015.
10. TechTerms.com. Wi-Fi. http://techterms.com/definition/wi-fi. Accessed April 14, 2015.
11. TechTerms.com. Bluetooth. http://techterms.com/definition/bluetooth. Accessed April 14, 2015.
12. TechTerms.com. Operating System. http://techterms.com/definition/operating_system. Accessed April 14, 2015.
13. TechTerms.com. iOS. http://techterms.com/definition/ios. Accessed April 14, 2015.
14. TechTarget. Android OS. http://searchenterpriselinux.techtarget.com/definition/Android. Accessed April 17, 2015.
15. TechTarget. Bandwidth. http://searchenterprisewan.techtarget.com/definition/bandwidth. Accessed April 17, 2015.
16. Baig MM, GholamHosseini H, Connolly MJ. Mobile healthcare applications: system design review, critical issues and challenges. *Australas Phys Eng Sci Med*. 2015;38:23–38. doi: 10.1007/s13246-014-0315-4.
17. Brennan PF. Telehealth: bringing health care to the point of living. *Med Care*. 1999;37:115–116.
18. Ahern DK, Kreslake JM, Phalen JM. What is eHealth (6): perspectives on the evolution of eHealth research. *J Med Internet Res*. 2006;8:e4. doi: 10.2196/jmir.8.1.e4.
19. Gustafson DH, Hawkins RP, Boberg EW, McTavish F, Owens B, Wise M, Berhe H, Pingree S. CHESS: 10 years of research and development in consumer health informatics for broad populations, including the underserved. *Int J Med Inform*. 2002;65:169–177.
20. Or CK, Karsh BT. A systematic review of patient acceptance of consumer health information technology. *J Am Med Informs Assoc*. 2009;16:550–560.
21. *Crossing the Quality Chasm: The IOM Health Care Quality Initiative*. Washington, DC: Institute of Medicine; 2001.
22. mHealth Alliance. mHealthKnowledge. http://www.mhealthalliance.org. 2013. Accessed October 23, 2013.
23. Boudreaux ED, Waring ME, Hayes RB, Sadasivam RS, Mullen S, Pagoto S. Evaluating and selecting mobile health apps: strategies for healthcare providers and healthcare organizations. *Transl Behav Med*. 2014;4:363–371. doi: 10.1007/s13142-014-0293-9.
24. US Food and Drug Administration. Mobile medical applications. http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ConnectedHealth/MobileMedicalApplications/ucm255978.htm. Accessed January 6, 2015.
25. Demiris G, Afrin LB, Speedie S, Courtney KL, Sondhi M, Vimarlund V, Lovis C, Goossen W, Lynch C. Patient-centered applications: use of information technology to promote disease management and wellness: a white paper by the AMIA Knowledge in Motion Working Group. *J Am Med Inform Assoc*. 2008;15:8–13. doi: 10.1197/jamia.M2492.
26. Brennan PF, Strombom I. Improving health care by understanding patient preferences: the role of computer technology. *J Am Med Inform Assoc*. 1998;5:257–262.

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27. Leena K, Tomi L, Arja RR. Intensity of mobile phone use and health compromising behaviours: how is information and communication technology connected to health-related lifestyle in adolescence? *J Adolesc*. 2005;28:35–47. doi: 10.1016/j.adolescence.2004.05.004.
28. Smith A. Mobile access 2010. 2010. http://www.pewinternet.org/files/old-media//Files/Reports/2010/PIP_Mobile_Access_2010.pdf. Accessed October. 28, 2014
29. Pew Research Internet Project: cell phone and smartphone ownership demographics. 2014. http://www.pewinternet.org/data-trend/mobile/cell-phone-and-smartphone-ownership-demographics/. Accessed October 23, 2014.
30. Pew Research Internet Project: mobile technology fact sheet. 2014. http://www.pewinternet.org/fact-sheets/mobile-technology-fact-sheet/. Accessed October 20, 2014.
31. Breton ER, Fuemmeler BF, Abroms LC. Weight loss: there is an app for that! But does it adhere to evidence-informed practices? *Transl Behav Med*. 2011;1:523–529. doi: 10.1007/s13142-011-0076-5.
32. Azar KM, Lesser LI, Laing BY, Stephens J, Aurora MS, Burke LE, Palaniappan LP. Mobile applications for weight management: theory-based content analysis. *Am J Prev Med*. 2013;45:583–589. doi: 10.1016/j.amepre.2013.07.005.
33. Petakov A, Nesmith K. Weight loss using evidence-based strategies in mobile apps. *Am J Prev Med*. 2014;47:e1. doi: 10.1016/j.amepre.2014.03.015.
34. Conroy DE, Yang CH, Maher JP. Behavior change techniques in top-ranked mobile apps for physical activity. *Am J Prev Med*. 2014;46:649–652. doi: 10.1016/j.amepre.2014.01.010.
35. Gibbons MC, Wilson RF, Samal L, Lehmann CU, Dickersin K, Lehmann HP, Aboumatar H, Finkelstein J, Shelton E, Sharma R, Bass EB. Consumer health informatics: results of a systematic evidence review and evidence based recommendations. *Transl Behav Med*. 2011;1:72–82. doi: 10.1007/s13142-011-0016-4.
36. Mosa AS, Yoo I, Sheets L. A systematic review of healthcare applications for smartphones. *BMC Med Inform Decis Mak*. 2012;12:67. doi: 10.1186/1472-6947-12-67.
37. Lefebvre RC, Bornkessel AS. Digital social networks and health. *Circulation*. 2013;127:1829–1836. doi: 10.1161/CIRCULATIONAHA.112.000897.
38. Walsh JA 3rd, Topol EJ, Steinhubl SR. Novel wireless devices for cardiac monitoring. *Circulation*. 2014;130:573–581. doi: 10.1161/CIRCULATIONAHA.114.009024.
39. Fox S, Rainie L. Pew Research Internet project: the Web at 25 in the U.S. 2014. http://www.pewinternet.org/2014/02/27/the-web-at-25-in-the-u-s/. Accessed January 9, 2015.
40. Ford ES, Croft JB, Posner SF, Goodman RA, Giles WH. Co-occurrence of leading lifestyle-related chronic conditions among adults in the United States, 2002–2009. *Prev Chronic Dis*. 2013;10:E60.
41. Prados-Torres A, Poblador-Plou B, Calderón-Larrañaga A, Gimeno-Feliu LA, González-Rubio F, Poncel-Falcó A, Sicras-Mainar A, Alcalá-Nalvaiz JT. Multimorbidity patterns in primary care: interactions among chronic diseases using factor analysis. *PLoS One*. 2012;7:e32190. doi: 10.1371/journal.pone.0032190.
42. Goodman RA, Posner SF, Huang ES, Parekh AK, Koh HK. Defining and measuring chronic conditions: imperatives for research, policy, program, and practice. *Prev Chronic Dis*. 2013;10:E66. doi: 10.5888/pcd10.120239.
43. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011–2012. *JAMA*. 2014;311:806–814. doi: 10.1001/jama.2014.732.
44. Deleted in proof.
45. Van den Akker M, Buntix F, Knottnerus JA. Comorbidity or multimorbidity: what's in a name? A review of literature. *Eur J Gen Pract*. 1996;2:65–70.
46. Marengoni A, Angleman S, Melis R, Mangialasche F, Karp A, Garmen A, Meinow B, Fratiglioni L. Aging with multimorbidity: a systematic review of the literature. *Ageing Res Rev*. 2011;10:430–439. doi: 10.1016/j.arr.2011.03.003.
47. Machlin SR, Soni A. Health care expenditures for adults with multiple treated chronic conditions: estimates from the Medical Expenditure Panel Survey, 2009. *Prev Chronic Dis*. 2013;10:E63.
48. Steiner CA, Friedman B. Hospital utilization, costs, and mortality for adults with multiple chronic conditions, Nationwide Inpatient Sample, 2009. *Prev Chronic Dis*. 2013;10:E62.
49. Brettschneider C, Leicht H, Bickel H, Dahlhaus A, Fuchs A, Gensichen J, Maier W, Riedel-Heller S, Schäfer I, Schön G, Weyerer S, Wiese B, van den Bussche H, Scherer M, König HH; MultiCare Study Group. Relative impact of multimorbid chronic conditions on health-related quality of life: results from the MultiCare Cohort Study. *PLoS One*. 2013;8:e66742. doi: 10.1371/journal.pone.0066742.
50. Fortin M, Bravo G, Hudon C, Lapointe L, Dubois MF, Almirall J. Psychological distress and multimorbidity in primary care. *Ann Fam Med*. 2006;4:417–422. doi: 10.1370/afm.528.
51. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM; Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346:393–403. doi: 10.1056/NEJMoa012512.
52. Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, Keinänen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M; Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344:1343–1350. doi: 10.1056/NEJM200105033441801.
53. Appel LJ, Champagne CM, Harsha DW, Cooper LS, Obarzanek E, Elmer PJ, Stevens VJ, Vollmer WM, Lin PH, Svetkey LP, Stedman SW, Young DR; Writing Group of the PREMIER Collaborative Research Group. Effects of comprehensive lifestyle modification on blood pressure control: main results of the PREMIER clinical trial. *JAMA*. 2003;289:2083–2093. doi: 10.1001/jama.289.16.2083.
54. Stevens VJ, Obarzanek E, Cook NR, Lee IM, Appel LJ, Smith West D, Milas NC, Mattfeldt-Beman M, Belden L, Bragg C, Millstone M, Raczynski J, Brewer A, Singh B, Cohen J; Trials for the Hypertension Prevention Research Group. Long-term weight loss and changes in blood pressure: results of the Trials of Hypertension Prevention, phase II. *Ann Intern Med*. 2001;134:1–11.
55. Look AHEAD Research Group, Wing RR. Long-term effects of a lifestyle intervention on weight and cardiovascular risk factors in individuals with type 2 diabetes mellitus: four-year results of the Look AHEAD trial. *Arch Intern Med*. 2010;170:1566–1575. doi: 10.1001/archinternmed.2010.334.
56. Look AHEAD Research Group, Pi-Sunyer X, Blackburn G, Brancati FL, Bray GA, Bright R, Clark JM, Curtis JM, Espeland MA, Foreyt JP, Graves K, Haffner SM, Harrison B, Hill JO, Horton ES, Jakicic J, Jeffery RW, Johnson KC, Kahn S, Kelley DE, Kitabchi AE, Knowler WC, Lewis CE, Maschak-Carey BJ, Montgomery B, Nathan DM, Patricio J, Peters A, Redmon JB, Reeves RS, Ryan DH, Safford M, Van Dorsten B, Wadden TA, Wagenknecht L, Wesche-Thobaben J, Wing RR, Yanovski SZ. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the Look AHEAD Trial. *Diabetes Care*. 2007;30:1374–1383.
57. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, Hu FB, Hubbard VS, Jakicic JM, Kushner RF, Loria CM, Millen BE, Nonas CA, Pi-Sunyer FX, Stevens J, Stevens VJ, Wadden TA, Wolfe BM, Yanovski SZ. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society [published correction appears in *Circulation*. 2014;129(suppl 2):S139–S140]. *Circulation*. 2014;129(suppl 2):S102–S138. doi: 10.1161/01.cir.0000437739.71477.ee.
58. Thomas JG, Bond DS. Review of innovations in digital health technology to promote weight control. *Curr Diab Rep*. 2014;14:485. doi: 10.1007/s11892-014-0485-1.
59. Nguyen B, Kornman KP, Baur LA. A review of electronic interventions for prevention and treatment of overweight and obesity in young people. *Obes Rev*. 2011;12:e298–e314. doi: 10.1111/j.1467-789X.2010.00830.x.
60. Coons MJ, Demott A, Buscemi J, Duncan JM, Pellegrini CA, Steglitz J, Pictor A, Spring B. Technology interventions to curb obesity: a systematic review of the current literature. *Curr Cardiovasc Risk Rep*. 2012;6:120–134. doi: 10.1007/s12170-012-0222-8.
61. Arem H, Irwin M. A review of web-based weight loss interventions in adults. *Obes Rev*. 2011;12:e236–e243. doi: 10.1111/j.1467-789X.2010.00787.x.
62. Manzoni GM, Pagnini F, Corti S, Molinari E, Castelnuovo G. Internet-based behavioral interventions for obesity: an updated systematic review. *Clin Pract Epidemiol Ment Health*. 2011;7:19–28. doi: 10.2174/1745017901107010019.
63. Neve M, Morgan PJ, Jones PR, Collins CE. Effectiveness of web-based interventions in achieving weight loss and weight loss maintenance in overweight and obese adults: a systematic review with meta-analysis. *Obes Rev*. 2010;11:306–321. doi: 10.1111/j.1467-789X.2009.00646.x.
64. Bacigalupo R, Cudd P, Littlewood C, Bissell P, Hawley MS, Buckley Woods H. Interventions employing mobile technology for overweight and obesity: an early systematic review of randomized controlled trials. *Obes Rev*. 2013;14:279–291. doi: 10.1111/obr.12006.

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65. Stephens J, Allen J. Mobile phone interventions to increase physical activity and reduce weight: a systematic review. *J Cardiovasc Nurs*. 2013;28:320–329. doi: 10.1097/JCN.0b013e318250a3e7.
66. Siopis G, Chey T, Allman-Farinelli M. A systematic review and meta-analysis of interventions for weight management using text messaging. *J Hum Nutr Diet*. 2015;28(suppl 2):1–15. doi: 10.1111/jhn.12207.
67. Shaw R, Bosworth H. Short message service (SMS) text messaging as an intervention medium for weight loss: a literature review. *Health Informatics J*. 2012;18:235–250. doi: 10.1177/1460458212442422.
68. Derbyshire E, Dancey D. Smartphone medical applications for women's health: what is the evidence-base and feedback? *Int J Telemed Appl*. 2013;2013:782074. doi: 10.1155/2013/782074.
69. Khaylis A, Yiaslas T, Bergstrom J, Gore-Felton C. A review of efficacious technology-based weight-loss interventions: five key components. *Telemed J E Health*. 2010;16:931–938. doi: 10.1089/tmj.2010.0065.
70. Tang J, Abraham C, Greaves C, Yates T. Self-directed interventions to promote weight loss: a systematic review of reviews. *J Med Internet Res*. 2014;16:e58. doi: 10.2196/jmir.2857.
71. Valbuena DA. *Evaluating the Effectiveness of an Internet-Based Behavioral Program for Increasing Physical Activity With and Without a Behavioral Coach*. Tampa, FL: Department of Child and Family Studies, University of South Florida; 2013.
72. Bennett GG, Warner ET, Glasgow RE, Askew S, Goldman J, Ritzwoller DP, Emmons KM, Rosner BA, Colditz GA; Be Fit, Be Well Study Investigators. Obesity treatment for socioeconomically disadvantaged patients in primary care practice. *Arch Intern Med*. 2012;172:565–574. doi: 10.1001/archinternmed.2012.1.
73. Haapala I, Barengo NC, Biggs S, Surakka L, Manninen P. Weight loss by mobile phone: a 1-year effectiveness study. *Public Health Nutr*. 2009;12:2382–2391. doi: 10.1017/S1368980009005230.
74. Patrick K, Raab F, Adams MA, Dillon L, Zabinski M, Rock CL, Griswold WG, Norman GJ. A text message-based intervention for weight loss: randomized controlled trial. *J Med Internet Res*. 2009;11:e1. doi: 10.2196/jmir.1100.
75. Turner-McGrievy GM, Campbell MK, Tate DF, Truesdale KP, Bowling JM, Crosby L. Pounds Off Digitally study: a randomized podcasting weight-loss intervention. *Am J Prev Med*. 2009;37:263–269. doi: 10.1016/j.amepre.2009.06.010.
76. Shuger SL, Barry VW, Sui X, McClain A, Hand GA, Wilcox S, Meriwether RA, Hardin JW, Blair SN. Electronic feedback in a diet- and physical activity-based lifestyle intervention for weight loss: a randomized controlled trial. *Int J Behav Nutr Phys Act*. 2011;8:41. doi: 10.1186/1479-5868-8-41.
77. Burke LE, Styn MA, Sereika SM, Conroy MB, Ye L, Glanz K, Sevick MA, Ewing LJ. Using mHealth technology to enhance self-monitoring for weight loss: a randomized trial. *Am J Prev Med*. 2012;43:20–26. doi: 10.1016/j.amepre.2012.03.016.
78. Burke LE, Conroy MB, Sereika SM, Elci OU, Styn MA, Acharya SD, Sevick MA, Ewing LJ, Glanz K. The effect of electronic self-monitoring on weight loss and dietary intake: a randomized behavioral weight loss trial. *Obesity (Silver Spring)*. 2011;19:338–344. doi: 10.1038/oby.2010.208.
79. Shapiro JR, Koro T, Doran N, Thompson S, Sallis JF, Calfas K, Patrick K. Text4Diet: a randomized controlled study using text messaging for weight loss behaviors. *Prev Med*. 2012;55:412–417. doi: 10.1016/j.ypmed.2012.08.011.
80. Turner-McGrievy G, Tate D. Tweets, apps, and pods: results of the 6-month Mobile Pounds Off Digitally (Mobile POD) randomized weight-loss intervention among adults. *J Med Internet Res*. 2011;13:e120. doi: 10.2196/jmir.1841.
81. Turner-McGrievy GM, Beets MW, Moore JB, Kaczynski AT, Barr-Anderson DJ, Tate DF. Comparison of traditional versus mobile app self-monitoring of physical activity and dietary intake among overweight adults participating in an mHealth weight loss program. *J Am Med Inform Assoc*. 2013;20:513–518. doi: 10.1136/amiajnl-2012-001510.
82. Carter MC, Burley VJ, Nykjaer C, Cade JE. Adherence to a smartphone application for weight loss compared to website and paper diary: pilot randomized controlled trial. *J Med Internet Res*. 2013;15:e32. doi: 10.2196/jmir.2283.
83. Napolitano MA, Hayes S, Bennett GG, Ives AK, Foster GD. Using Facebook and text messaging to deliver a weight loss program to college students. Obesity (Silver Spring). 2013;21:25–31. doi: 10.1002/oby.20232.
84. Spring B, Duncan JM, Janke EA, Kozak AT, McFadden HG, DeMott A, Pictor A, Epstein LH, Siddique J, Pellegrini CA, Buscemi J, Hedeker D. Integrating technology into standard weight loss treatment: a randomized controlled trial. JAMA Intern Med. 2013;173:105–111. doi: 10.1001/jamainternmed.2013.1221.
85. Bennett GG, Steinberg DM, Stoute C, Lanpher M, Lane I, Askew S, Foley PB, Baskin ML. Electronic health (eHealth) interventions for weight management among racial/ethnic minority adults: a systematic review. *Obes Rev*. 2014;15(suppl 4):146–158. doi: 10.1111/obr.12218.
86. Smith A. Smartphone ownership 2013. 2013. http://www.pewinternet.org/2013/06/05/smartphone-ownership-2013. Accessed September 18, 2014.
87. Eysenbach G. The law of attrition. *J Med Internet Res*. 2005;7:e11. doi: 10.2196/jmir.7.1.e11.
88. Almirall D, Nahum-Shani I, Sherwood NE, Murphy SA. Introduction to SMART designs for the development of adaptive interventions: with application to weight loss research. *Transl Behav Med*. 2014;4:260–274. doi: 10.1007/s13142-014-0265-0.
89. Shiffman S. Real-time self-report of momentary states in the natural environment: computerized ecological momentary assessment. In: Stone AA, Bachrach CA, Jobe JB., Kurtzman HS., Cain VS, eds. *The Science of Self Report: Implications for Research and Practice*. Mahwah, NJ: Erlbaun; 2000:277–296.
90. McKee HC, Ntoumanis N, Taylor IM. An ecological momentary assessment of lapse occurrences in dieters. *Ann Behav Med*. 2014;48:300–310. doi: 10.1007/s12160-014-9594-y.
91. Thompson PD, Buchner D, Pina IL, Balady GJ, Williams MA, Marcus BH, Berra K, Blair SN, Costa F, Franklin B, Fletcher GF, Gordon NF, Pate RR, Rodriguez BL, Yancey AK, Wenger NK. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*. 2003;107:3109–3116. doi: 10.1161/01.CIR.0000075572.40158.77.
92. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med*. 2010;39:305–313. doi: 10.1016/j.amepre.2010.06.006.
93. US Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. http://www.health.gov/paguidelines/pdf/paguide.pdf. Accessed October 28, 2014.
94. Office of Disease Prevention and Health Promotion. Physical activity has many health benefits. http://www.health.gov/paguidelines/guidelines/chapter2.aspx. Accessed October. 28, 2014.
95. Ladabaum U, Mannalithara A, Myer PA, Singh G. Obesity, abdominal obesity, physical activity, and caloric intake in US adults: 1988 to 2010. *Am J Med*. 2014;127:717–727.e712. doi: 10.1016/j.amjmed.2014.02.026.
96. *Health, United States, 2013: With Special Feature on Prescription Drugs*. Hyattsville, MD: US National Center for Health Statistics; 2014.
97. Plotnikoff RC, McCargar LJ, Wilson PM, Loucaides CA. Efficacy of an E-mail intervention for the promotion of physical activity and nutrition behavior in the workplace context. *Am J Health Promot*. 2005;19:422–429.
98. Hurling R, Catt M, Boni MD, Fairley BW, Hurst T, Murray P, Richardson A, Sodhi JS. Using Internet and mobile phone technology to deliver an automated physical activity program: randomized controlled trial. *J Med Internet Res*.
99. Spittaels H, De Bourdeaudhuij I, Brug J, Vandelanotte C. Effectiveness of an online computer-tailored physical activity intervention in a real-life setting. *Health Educ Res*. 2007;22:385–396. doi: 10.1093/her/cyl096.
100. Dunton GF, Robertson TP. A tailored Internet-plus-email intervention for increasing physical activity among ethnically-diverse women. *Prev Med*. 2008;47:605–611. doi: 10.1016/j.ypmed.2008.10.004.
101. King AC, Ahn DK, Oliveira BM, Atienza AA, Castro CM, Gardner CD. Promoting physical activity through hand-held computer technology. *Am J Prev Med*. 2008;34:138–142. doi: 10.1016/j.amepre.2007.09.025.
102. Ferney SL, Marshall AL, Eakin EG, Owen N. Randomized trial of a neighborhood environment-focused physical activity website intervention. *Prev Med*. 2009;48:144–150. doi: 10.1016/j.ypmed.2008.10.022.
103. Fjeldsoe BS, Miller YD, Marshall AL. MobileMums: a randomized controlled trial of an SMS-based physical activity intervention. *Ann Behav Med*. 2010;39:101–111. doi: 10.1007/s12160-010-9170-z.
104. Richardson CR, Buis LR, Janney AW, Goodrich DE, Sen A, Hess ML, Mehari KS, Fortlage LA, Resnick PJ, Zikmund-Fisher BJ, Strecher VJ, Piette JD. An online community improves adherence in an Internet-mediated walking program, part 1: results of a randomized controlled trial. *J Med Internet Res*. 2010;12:e71. doi: 10.2196/jmir.1338.
105. Aittasalo M, Rinne M, Pasanen M, Kukkonen-Harjula K, Vasankari T. Promoting walking among office employees: evaluation of a randomized

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controlled intervention with pedometers and e-mail messages. *BMC Public Health*. 2012;12:403. doi: 10.1186/1471-2458-12-403.
106. Reid RD, Morrin LI, Beaton LJ, Papadakis S, Kocourek J, McDonnell L, Slovinec D'Angelo ME, Tulloch H, Suskin N, Unsworth K, Blanchard C, Pipe AL. Randomized trial of an internet-based computer-tailored expert system for physical activity in patients with heart disease. *Eur J Prev Cardiol*. 2012;19:1357–1364. doi: 10.1177/1741826711422988.
107. Bickmore TW, Silliman RA, Nelson K, Cheng DM, Winter M, Henault L, Paasche-Orlow MK. A randomized controlled trial of an automated exercise coach for older adults. *J Am Geriatr Soc*. 2013;61:1676–1683. doi: 10.1111/jgs.12449.
108. Gotsis M, Wang H, Spruijt-Metz D, Jordan-Marsh M, Valente TW. Wellness partners: design and evaluation of a web-based physical activity diary with social gaming features for adults. *JMIR Res Protoc*. 2013;2:e10. doi: 10.2196/resprot.2132.
109. Kim BH, Glanz K. Text messaging to motivate walking in older African Americans: a randomized controlled trial. *Am J Prev Med*. 2013;44:71–75. doi: 10.1016/j.amepre.2012.09.050.
110. King AC, Hekler EB, Castro CM, Buman MP, Marcus BH, Friedman RH, Napolitano MA. Exercise advice by humans versus computers: maintenance effects at 18 months. *Health Psychol*. 2014;33:192–196. doi: 10.1037/a0030646.
111. Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: a systematic review. *Sports Med*. 2014;44:671–686. doi: 10.1007/s40279-014-0142-5.
112. Buchholz SW, Wilbur J, Ingram D, Fogg L. Physical activity text messaging interventions in adults: a systematic review. *Worldviews Evid Based Nurs*. 2013;10:163–173. doi: 10.1111/wvn.12002.
113. Peng W, Crouse JC, Lin JH. Using active video games for physical activity promotion: a systematic review of the current state of research. *Health Educ Behav*. 2013;40:171–192. doi: 10.1177/1090198112444956.
114. Yang CC, Hsu YL. A review of accelerometry-based wearable motion detectors for physical activity monitoring. *Sensors (Basel)*. 2010;10:7772–7788. doi: 10.3390/s100807772.
115. Fox S, Duggan M. Pew Research Internet Project tracking for health main report. 2013. http://www.pewinternet.org/2013/01/28/main-report-8/. Accessed October 28, 2014.
116. Lee JM, Kim Y, Welk GJ. Validity of consumer-based physical activity monitors. *Med Sci Sports Exerc*. 2014;46:1840–1848. doi: 10.1249/MSS.0000000000000287.
117. Ockene IS, Miller NH. Cigarette smoking, cardiovascular disease, and stroke: a statement for healthcare professionals from the American Heart Association. American Heart Association Task Force on Risk Reduction. *Circulation*. 1997;96:3243–3247.
118. Fiore M, Jaén C, Baker T, Bailey W, Benowitz N, Curry S. *Treating Tobacco Use and Dependence: 2008 Update: Clinical Practice Guideline: Executive Summary*. Rockville, MD: US Department of Health and Human Services, Public Health Service; 2008.
119. Tong EK, Strouse R, Hall J, Kovac M, Schroeder SA. National survey of U.S. health professionals' smoking prevalence, cessation practices, and beliefs. *Nicotine Tob Res*. 2010;12:724–733. doi: 10.1093/ntr/ntq071.
120. Civljak M, Stead LF, Hartmann-Boyce J, Sheikh A, Car J. Internet-based interventions for smoking cessation. *Cochrane Database Syst Rev*. 2013;7:CD007078. doi: 10.1002/14651858.CD007078.pub4.
121. Gilliland SS, Azen SP, Perez GE, Carter JS. Strong in body and spirit: lifestyle intervention for Native American adults with diabetes in New Mexico. *Diabetes Care*. 2002;25:78–83.
122. McClernon FJ, Roy Choudhury R. I am your smartphone, and I know you are about to smoke: the application of mobile sensing and computing approaches to smoking research and treatment. *Nicotine Tob Res*. 2013;15:1651–1654. doi: 10.1093/ntr/ntt054.
123. Abroms LC, Lee Westmaas J, Bontemps-Jones J, Ramani R, Mellerson J. A content analysis of popular smartphone apps for smoking cessation. *Am J Prev Med*. 2013;45:732–736. doi: 10.1016/j.amepre.2013.07.008.
124. Abroms LC, Padmanabhan N, Thaweethai L, Phillips T. iPhone apps for smoking cessation: a content analysis. *Am J Prev Med*. 2011;40:279–285. doi: 10.1016/j.amepre.2010.10.032.
125. Cinciripini PM, Wetter DW, McClure JB. Scheduled reduced smoking: effects on smoking abstinence and potential mechanisms of action. *Addict Behav*. 1997;22:759–767.
126. Ybarra ML, Holtrop JS, Prescott TL, Rahbar MH, Strong D. Pilot RCT results of stop my smoking USA: a text messaging-based smoking cessation program for young adults. *Nicotine Tob Res*. 2013;15:1388–1399. doi: 10.1093/ntr/nts339.
127. Abroms LC, Boal AL, Simmens SJ, Mendel JA, Windsor RA. A randomized trial of Text2Quit: a text messaging program for smoking cessation. *Am J Prev Med*. 2014;47:242–250. doi: 10.1016/j.amepre.2014.04.010.
128. Rodgers A, Corbett T, Bramley D, Riddell T, Wills M, Lin RB, Jones M. Do u smoke after txt? Results of a randomised trial of smoking cessation using mobile phone text messaging. *Tob Control*. 2005;14:255–261. doi: 10.1136/tc.2005.011577.
129. Brendryen H, Drozd F, Kraft P. A digital smoking cessation program delivered through Internet and cell phone without nicotine replacement (Happy Ending): randomized controlled trial. *J Med Internet Res*. 2008;10:e51. doi: 10.2196/jmir.1005.
130. Brendryen H, Kraft P. Happy Ending: a randomized controlled trial of a digital multi-media smoking cessation intervention. *Addiction*. 2008;103:478–484. doi: 10.1111/j.1360-0443.2007.02119.x.
131. Free C, Whittaker R, Knight R, Abramsky T, Rodgers A, Roberts IG. Txt2stop: a pilot randomised controlled trial of mobile phone-based smoking cessation support. *Tob Control*. 2009;18:88–91. doi: 10.1136/tc.2008.026146.
132. Free C, Knight R, Robertson S, Whittaker R, Edwards P, Zhou W, Rodgers A, Cairns J, Kenward MG, Roberts I. Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. *Lancet*. 2011;378:49–55. doi: 10.1016/S0140-6736(11)60701-0.
133. Whittaker R, Dorey E, Bramley D, Bullen C, Denny S, Elley CR, Maddison R, McRobbie H, Parag V, Rodgers A, Salmon P. A theory-based video messaging mobile phone intervention for smoking cessation: randomized controlled trial. *J Med Internet Res*. 2011;13:e10. doi: 10.2196/jmir.1553.
134. Naughton F, Prevost AT, Gilbert H, Sutton S. Randomized controlled trial evaluation of a tailored leaflet and SMS text message self-help intervention for pregnant smokers (MiQuit). *Nicotine Tob Res*. 2012;14:569–577. doi: 10.1093/ntr/ntr254.
135. Ybarra M, Bağci Bosi AT, Korchmaros J, Emri S. A text messaging-based smoking cessation program for adult smokers: randomized controlled trial [published correction appears in *J Med Internet Res*. 2015;17:e125]. *J Med Internet Res*. 2012;14:e172. doi: 10.2196/jmir.2231.
136. Borland R, Balmford J, Benda P. Population-level effects of automated smoking cessation help programs: a randomized controlled trial. *Addiction*. 2013;108:618–628. doi: 10.1111/j.1360-0443.2012.04091.x.
137. Ali MK, Bullard KM, Saaddine JB, Cowie CC, Imperatore G, Gregg EW. Achievement of goals in U.S. diabetes care, 1999–2010 [published correction appears in *N Engl J Med*. 2013;369:587]. *N Engl J Med*. 2013;368:1613–1624.
138. Haug S, Schaub MP, Venzin V, Meyer C, John U. Efficacy of a text message-based smoking cessation intervention for young people: a cluster randomized controlled trial. *J Med Internet Res*. 2013;15:e171. doi: 10.2196/jmir.2636.
139. Shi HJ, Jiang XX, Yu CY, Zhang Y. Use of mobile phone text messaging to deliver an individualized smoking behaviour intervention in Chinese adolescents. *J Telemed Telecare*. 2013;19:282–287. doi: 10.1177/1357633X13495489.
140. Whittaker R, Borland R, Bullen C, Lin RB, McRobbie H, Rodgers A. Mobile phone-based interventions for smoking cessation. *Cochrane Database Syst Rev*. 2009:CD006611. doi: 10.1002/14651858.CD006611.pub2.
141. Whittaker R, McRobbie H, Bullen C, Borland R, Rodgers A, Gu Y. Mobile phone-based interventions for smoking cessation. *Cochrane Database Syst Rev*. 2012;11:CD006611. doi: 10.1002/14651858.CD006611.pub3.
142. Obermayer JL, Riley WT, Asif O, Jean-Mary J. College smoking-cessation using cell phone text messaging. *J Am Coll Health*. 2004;53:71–78. doi: 10.3200/JACH.53.2.71-78.
143. Fox S, Duggan M. Mobile health 2012. http://www.pewinternet.org/files/old-media/Files/Reports/2012/PIP_MobileHealth2012_FINAL.pdf. Accessed October 23, 2014.
144. Barbeau EM, Krieger N, Soobader MJ. Working class matters: socioeconomic disadvantage, race/ethnicity, gender, and smoking in NHIS 2000 [published correction appears in *Am J Public Health*. 2004;94:1295]. *Am J Public Health*. 2004;94:269–278.
145. Hartmann-Boyce J, Stead LF, Cahill K, Lancaster T. Efficacy of interventions to combat tobacco addiction: Cochrane update of 2012 reviews. *Addiction*. 2013;108:1711–1721.
146. Centers for Disease Control and Prevention. Blood glucose daily self-monitoring: rate of daily self-monitoring among adults with diabetes aged 18 years and older, 1997–2006. http://www.cdc.gov/datastatistics/2007/bloodglucose/. Accessed October 28, 2014.

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Circulation American Heart Association

147. Heron KE, Smyth JM. Ecological momentary interventions: incorporating mobile technology into psychosocial and health behaviour treatments. *Br J Health Psychol*. 2010;15(pt 1):1–39. doi: 10.1348/135910709X466063.
148. Riley W, Obermayer J, Jean-Mary J. Internet and mobile phone text messaging intervention for college smokers. *J Am Coll Health*. 2008;57:245–248. doi: 10.3200/JACH.57.2.245-248.
148a. Bock B, Heron K, Jennings E, Morrow K, Cobb V, Magee J, Fava J, Deutsch C, Foster R. A text message delivered smoking cessation intervention: the initial trial of TXT-2 Quit: randomized controlled trial. *JMIR Mhealth Uhealth*. 2013;1:e17. doi: 10.2196/mhealth.2522.
149. Schneider A, Wensing M, Quinzler R, Bieber C, Szecsenyi J. Higher preference for participation in treatment decisions is associated with lower medication adherence in asthma patients. *Patient Educ Couns*. 2007;67:57–62. doi: 10.1016/j.pec.2007.01.019.
150. Preis SR, Pencina MJ, Hwang SJ, D'Agostino RB Sr, Savage PJ, Levy D, Fox CS. Trends in cardiovascular disease risk factors in individuals with and without diabetes mellitus in the Framingham Heart Study. *Circulation*. 2009;120:212–220. doi: 10.1161/CIRCULATIONAHA.108.846519.
151. Skyler JS, Bergenstal R, Bonow RO, Buse J, Deedwania P, Gale EAM, Howard BV, Kirkman MS, Kosiborod M, Reaven P, Sherwin RS. Intensive glycemic control and the prevention of cardiovascular events: implications of the ACCORD, ADVANCE, and VA Diabetes Trials: a position statement of the American Diabetes Association and a scientific statement of the American College of Cardiology Foundation and the American Heart Association [published correction appears in *Circulation*. 2009;119:e605]. *Circulation*. 2009;119:351–357. doi: 10.1161/CIRCULATIONAHA.108.191305.
152. Mulcahy K, Maryniuk M, Peeples M, Peyrot M, Tomky D, Weaver T, Yarborough P. Diabetes self-management education core outcomes measures. *Diabetes Educ*. 2003;29:768–770, 773–784, 787–788.
153. Haas L, Maryniuk M, Beck J, Cox CE, Duker P, Edwards L, Fisher EB, Hanson L, Kent D, Kolb L, McLaughlin S, Orzeck E, Piette JD, Rhinehart AS, Rothman R, Sklaroff S, Tomky D, Youssef G; 2012 Standards Revision Task Force. National standards for diabetes self-management education and support. *Diabetes Care*. 2013;36(suppl 1):S100–S108. doi: 10.2337/dc13-S100.
154. Deleted in proof.
155. Katz R, Mesfin T, Barr K. Lessons from a community-based mHealth diabetes self-management program: "it's not just about the cell phone." *J Health Commun*. 2012;17(suppl 1):67–72. doi: 10.1080/10810730.2012.650613.
156. Kim HS. A randomized controlled trial of a nurse short-message service by cellular phone for people with diabetes. *Int J Nurs Stud*. 2007;44:687–692.
157. Kim HS, Jeong HS. A nurse short message service by cellular phone in type-2 diabetic patients for six months. *J Clin Nurs*. 2007;16:1082–1087. doi: 10.1111/j.1365-2702.2007.01698.x.
158. Faridi Z, Liberti L, Shuval K, Northrup V, Ali A, Katz DL. Evaluating the impact of mobile telephone technology on type 2 diabetic patients' self-management: the dNICHE pilot study. *J Eval Clin Pract*. 2008;14:465–469. doi: 10.1111/j.1365-2753.2007.00881.x.
159. Kim HS, Song MS. Technological intervention for obese patients with type 2 diabetes. *Appl Nurs Res*. 2008;21:84–89. doi: 10.1016/j.apnr.2007.01.007.
160. Kim SI, Kim HS. Effectiveness of mobile and internet intervention in patients with obese type 2 diabetes. *Int J Med Inform*. 2008;77:399–404. doi: 10.1016/j.ijmedinf.2007.07.006.
161. Yoon KH, Kim HS. A short message service by cellular phone in type 2 diabetic patients for 12 months. *Diabetes Res Clin Pract*. 2008;79:256–261. doi: 10.1016/j.diabres.2007.09.007.
162. Istepanian RS, Zitouni K, Harry D, Moutosammy N, Sungoor A, Tang B, Earle KA. Evaluation of a mobile phone telemonitoring system for glycaemic control in patients with diabetes. *J Telemed Telecare*. 2009;15:125–128. doi: 10.1258/jtt.2009.003006.
163. Rodríguez-Idígoras MI, Sepúlveda-Muñoz J, Sánchez-Garrido-Escudero R, Martínez-González JL, Escolar-Castelló JL, Paniagua-Gómez IM, Bernal-López R, Fuentes-Simón MV, Garófano-Serrano D. Telemedicine influence on the follow-up of type 2 diabetes patients. *Diabetes Technol Ther*. 2009;11:431–437. doi: 10.1089/dia.2008.0114.
164. Yoo HJ, Park MS, Kim TN, Yang SJ, Cho GJ, Hwang TG, Baik SH, Choi DS, Park GH, Choi KM. A Ubiquitous Chronic Disease Care system using cellular phones and the Internet. *Diabet Med*. 2009;26:628–635. doi: 10.1111/j.1464-5491.2009.02732.x.
165. Kim CS, Park SY, Kang JG, Lee SJ, Ihm SH, Choi MG, Yoo HJ. Insulin dose titration system in diabetes patients using a short messaging service automatically produced by a knowledge matrix. *Diabetes Technol Ther*. 2010;12:663–669. doi: 10.1089/dia.2010.0031.
166. Noh JH, Cho YJ, Nam HW, Kim JH, Kim DJ, Yoo HS, Kwon YW, Woo MH, Cho JW, Hong MH, Yoo JH, Gu MJ, Kim SA, An KE, Jang SM, Kim EK, Yoo HJ. Web-based comprehensive information system for self-management of diabetes mellitus. *Diabetes Technol Ther*. 2010;12:333–337. doi: 10.1089/dia.2009.0122.
167. Carter EL, Nunlee-Bland G, Callender C. A patient-centric, provider-assisted diabetes telehealth self-management intervention for urban minorities. *Perspect Health Inf Manag*. 2011;8:1b.
168. Lim S, Kang SM, Shin H, Lee HJ, Won Yoon J, Yu SH, Kim SY, Yoo SY, Jung HS, Park KS, Ryu JO, Jang HC. Improved glycemic control without hypoglycemia in elderly diabetic patients using the ubiquitous healthcare service, a new medical information system. *Diabetes Care*. 2011;34:308–313. doi: 10.2337/dc10-1447.
169. Quinn CC, Clough SS, Minor JM, Lender D, Okafor MC, Gruber-Baldini A. WellDoc mobile diabetes management randomized controlled trial: change in clinical and behavioral outcomes and patient and physician satisfaction. *Diabetes Technol Ther*. 2008;10:160–168. doi: 10.1089/dia.2008.0283.
170. Quinn CC, Shardell MD, Terrin ML, Barr EA, Ballew SH, Gruber-Baldini AL. Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control [published correction appears in *Diabetes Care*. 2013;36:3850]. *Diabetes Care*. 2011;34:1934–1942. doi: 10.2337/dc11-0366.
171. Orsama AL, Lähteenmäki J, Harno K, Kulju M, Wintergerst E, Schachner H, Stenger P, Leppänen J, Kaijanranta H, Salaspuro V, Fisher WA. Active assistance technology reduces glycosylated hemoglobin and weight in individuals with type 2 diabetes: results of a theory-based randomized trial. *Diabetes Technol Ther*. 2013;15:662–669. doi: 10.1089/dia.2013.0056.
172. Forjuoh SN, Bolin JN, Huber JC Jr, Vuong AM, Adepoju OE, Helduser JW, Begaye DS, Robertson A, Moudouni DM, Bonner TJ, McLeroy KR, Ory MG. Behavioral and technological interventions targeting glycemic control in a racially/ethnically diverse population: a randomized controlled trial. *BMC Public Health*. 2014;14:71. doi: 10.1186/1471-2458-14-71.
173. Liang X, Wang Q, Yang X, Cao J, Chen J, Mo X, Huang J, Wang L, Gu D. Effect of mobile phone intervention for diabetes on glycaemic control: a meta-analysis. *Diabet Med*. 2011;28:455–463. doi: 10.1111/j.1464-5491.2010.03180.x.
174. Pal K, Eastwood SV, Michie S, Farmer AJ, Barnard ML, Peacock R, Wood B, Inniss JD, Murray E. Computer-based diabetes self-management interventions for adults with type 2 diabetes mellitus. *Cochrane Database Syst Rev*. 2013;3:CD008776. doi: 10.1002/14651858.CD008776.pub2.
175. Klonoff DC, Bergenstal R, Blonde L, Boren SA, Church TS, Gaffaney J, Jovanovic L, Kendall DM, Kollman C, Kovatchev BP, Leippert C, Owens DR, Polonsky WH, Reach G, Renard E, Riddell MC, Rubin RR, Schnell O, Siminiero LM, Vigersky RA, Wilson DM, Wollitzer AO. Consensus report of the coalition for clinical research-self-monitoring of blood glucose. *J Diabetes Sci Technol*. 2008;2:1030–1053.
176. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus: the Diabetes Control and Complications Trial Research Group. *N Engl J Med*. 1993;329:977–986.
177. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33): UK Prospective Diabetes Study (UKPDS) Group [published correction appears in *Lancet*. 1999;354:602]. *Lancet*. 1998;352:837–853.
178. Nagrebetsky A, Larsen M, Craven A, Turner J, McRobert N, Murray E, Gibson O, Neil A, Tarassenko L, Farmer A. Stepwise self-titration of oral glucose-lowering medication using a mobile telephone-based telehealth platform in type 2 diabetes: a feasibility trial in primary care. *J Diabetes Sci Technol*. 2013;7:123–134.
179. Jimison H, Gorman P, Woods S, Nygren P, Walker M, Norris S, Hersh W. Barriers and drivers of health information technology use for the elderly, chronically ill, and underserved. *Evid Rep Technol Assess (Full Rep)*. 2008:1–1422.
180. Consumer Health Information Corp. Motivating patients to use smartphone health apps. http://www.consumer-health.com/press/2008/NewsReleaseSmartPhoneApps.php. Accessed January 10, 2015.

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Circulation

181. Minet L, Møller S, Vach W, Wagner L, Henriksen JE. Mediating the effect of self-care management intervention in type 2 diabetes: a meta-analysis of 47 randomised controlled trials. *Patient Educ Couns*. 2010;80:29–41. doi: 10.1016/j.pec.2009.09.033.
182. Cotter AP, Durant N, Agne AA, Cherrington AL. Internet interventions to support lifestyle modification for diabetes management: a systematic review of the evidence. *J Diabetes Complications*. 2014;28:243–251. doi: 10.1016/j.jdiacomp.2013.07.003.
183. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT Jr, Roccella EJ; the National High Blood Pressure Education Program Coordinating Committee. Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension*. 2003;42:1206–1252. doi: 10.1161/01.HYP.0000107251.49515.c2.
184. Gee ME, Bienek A, Campbell NR, Bancej CM, Robitaille C, Kaczorowski J, Joffres M, Dai S, Gwadry-Sridar F, Nolan RP. Prevalence of, and barriers to, preventive lifestyle behaviors in hypertension (from a national survey of Canadians with hypertension). *Am J Cardiol*. 2012;109:570–575. doi: 10.1016/j.amjcard.2011.09.051.
185. Reynolds MW, Fredman L, Langenberg P, Magaziner J. Weight, weight change, mortality in a random sample of older community-dwelling women. *J Am Geriatr Soc*. 1999;47:1409–1414.
186. Bodenheimer T, Wagner EH, Grumbach K. Improving primary care for patients with chronic illness: the chronic care model, part 2. *JAMA*. 2002;288:1909–1914.
187. Bodenheimer T, Lorig K, Holman H, Grumbach K. Patient self-management of chronic disease in primary care. *JAMA*. 2002;288:2469–2475.
188. Asch DA, Muller RW, Volpp KG. Automated hovering in health care: watching over the 5000 hours. *N Engl J Med*. 2012;367:1–3. doi: 10.1056/NEJMp1203869.
189. Pickering TG. Home blood pressure monitoring: a new standard method for monitoring hypertension control in treated patients. *Nat Clin Pract Cardiovasc Med*. 2008;5:762–763. doi: 10.1038/ncpcardio1374.
190. Green BB, Cook AJ, Ralston JD, Fishman PA, Catz SL, Carlson J, Carrell D, Tyll L, Larson EB, Thompson RS. Effectiveness of home blood pressure monitoring, Web communication, and pharmacist care on hypertension control: a randomized controlled trial [published correction appears in *JAMA*. 2009;302:1972]. *JAMA*. 2008;299:2857–2867. doi: 10.1001/jama.299.24.2857.
191. Madsen LB, Kirkegaard P, Pedersen EB. Blood pressure control during telemonitoring of home blood pressure: a randomized controlled trial during 6 months. *Blood Press*. 2008;17:78–86. doi: 10.1080/08037050801915468.
192. Cottrell E, Chambers R, O'Connell P. Using simple telehealth in primary care to reduce blood pressure: a service evaluation. *BMJ Open*. 2012;2. doi: 10.1136/bmjopen-2012-001391.
193. Kiselev AR, Gridnev VI, Shvartz VA, Posnenkova OM, Dovgalevsky PY. Active ambulatory care management supported by short message services and mobile phone technology in patients with arterial hypertension. *J Am Soc Hypertens*. 2012;6:346–355. doi: 10.1016/j.jash.2012.08.001.
194. Logan AG, Irvine MJ, McIsaac WJ, Tisler A, Rossos PG, Easty A, Feig DS, Cafazzo JA. Effect of home blood pressure telemonitoring with self-care support on uncontrolled systolic hypertension in diabetics. *Hypertension*. 2012;60:51–57. doi: 10.1161/HYPERTENSIONAHA.111.188409.
195. Nolan RP, Liu S, Shoemaker JK, Hachinski V, Lynn H, Mikulis DJ, Wennberg RA, Moy Lum-Kwong M, Zbib A. Therapeutic benefit of Internet-based lifestyle counselling for hypertension. *Can J Cardiol*. 2012;28:390–396. doi: 10.1016/j.cjca.2012.02.012.
196. Piette JD, Datwani H, Gaudioso S, Foster SM, Westphal J, Perry W, Rodríguez-Saldaña J, Mendoza-Avelares MO, Marinec N. Hypertension management using mobile technology and home blood pressure monitoring: results of a randomized trial in two low/middle-income countries. *Telemed J E Health*. 2012;18:613–620. doi: 10.1089/tmj.2011.0271.
197. Watson AJ, Singh K, Myint-U K, Grant RW, Jethwani K, Murachver E, Harris K, Lee TH, Kvedar JC. Evaluating a web-based self-management program for employees with hypertension and prehypertension: a randomized clinical trial. *Am Heart J*. 2012;164:625–631. doi: 10.1016/j.ahj.2012.06.013.
198. Magid DJ, Olson KL, Billups SJ, Wagner NM, Lyons EE, Kroner BA. A pharmacist-led, American Heart Association Heart360 Web-enabled home blood pressure monitoring program. *Circ Cardiovasc Qual Outcomes*. 2013;6:157–163. doi: 10.1161/CIRCOUTCOMES.112.968172.
199. McKinstry B, Hanley J, Wild S, Pagliari C, Paterson M, Lewis S, Sheikh A, Krishan A, Stoddart A, Padfield P. Telemonitoring based service redesign for the management of uncontrolled hypertension: multicentre randomised controlled trial. *BMJ*. 2013;346:f3030. doi: 10.1136/bmj.f3030.
200. Rifkin DE, Abdelmalek JA, Miracle CM, Low C, Barsotti R, Rios P, Stepnowsky C, Agha Z. Linking clinic and home: a randomized, controlled clinical effectiveness trial of real-time, wireless blood pressure monitoring for older patients with kidney disease and hypertension. *Blood Press Monit*. 2013;18:8–15. doi: 10.1097/MBP.0b013e32835d126c.
201. Thiboutot J, Sciamanna CN, Falkner B, Kephart DK, Stuckey HL, Adelman AM, Curry WJ, Lehman EB. Effects of a web-based patient activation intervention to overcome clinical inertia on blood pressure control: cluster randomized controlled trial. *J Med Internet Res*. 2013;15:e158. doi: 10.2196/jmir.2298.
202. Cicolini G, Simonetti V, Comparcini D, Celiberti I, Di Nicola M, Capasso LM, Flacco ME, Bucci M, Mezzetti A, Manzoli L. Efficacy of a nurse-led email reminder program for cardiovascular prevention risk reduction in hypertensive patients: a randomized controlled trial. *Int J Nurs Stud*. 2014;51:833–843. doi: 10.1016/j.ijnurstu.2013.10.010.
203. Uhlig K, Patel K, Ip S, Kitsios GD, Balk EM. Self-measured blood pressure monitoring in the management of hypertension: a systematic review and meta-analysis. *Ann Intern Med*. 2013;159:185–194. doi: 10.7326/0003-4819-159-3-201308060-00008.
204. Liu S, Dunford SD, Leung YW, Brooks D, Thomas SG, Eysenbach G, Nolan RP. Reducing blood pressure with Internet-based interventions: a meta-analysis. *Can J Cardiol*. 2013;29:613–621. doi: 10.1016/j.cjca.2013.02.007.
205. Fahey T, Schroeder K, Ebrahim S. Interventions used to improve control of blood pressure in patients with hypertension. *Cochrane Database Syst Rev*. 2006:CD005182.
206. Centers for Disease Control and Prevention. Cholesterol. http://www.cdc.gov/nchs/fastats/cholesterol.htm. Accessed July 10, 2014.
207. Lester WT, Grant R, Barnett GO, Chueh H. Facilitated lipid management using interactive e-mail: preliminary results of a randomized controlled trial. *Stud Health Technol Inform*. 2004;107(pt 1):232–236.
208. Strong JP, Malcom GT, McMahan CA, Tracy RE, Newman WP 3rd, Herderick EE, Cornhill JF. Prevalence and extent of atherosclerosis in adolescents and young adults: implications for prevention from the Pathobiological Determinants of Atherosclerosis in Youth Study. *JAMA*. 1999;281:727–735.
209. Berenson GS, Srinivasan SR, Bao W, Newman WP 3rd, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults: the Bogalusa Heart Study. *N Engl J Med*. 1998;338:1650–1656. doi: 10.1056/NEJM199806043382302.
210. McMahan CA, Gidding SS, Malcom GT, Schreiner PJ, Strong JP, Tracy RE, Williams OD, McGill HC; Pathobiological Determinants of Atherosclerosis in Youth (PDAY) Research Group. Comparison of coronary heart disease risk factors in autopsied young adults from the PDAY study with living young adults from the CARDIA study. *Cardiovasc Pathol*. 2007;16:151–158. doi: 10.1016/j.carpath.2006.12.003.
211. National Cholesterol Education Program (NCEP): highlights of the report of the Expert Panel on Blood Cholesterol Levels in Children and Adolescents. *Pediatrics*. 1992;89:495–501.
212. US Preventive Services Task Force. Lipid disorders in children: screening. 2007. http://www.uspreventiveservicestaskforce.org/uspstf07/chlipid/chlipidrs.htm. Accessed July 19, 2013.
213. Daniels SR, Greer FR; Committee on Nutrition. Lipid screening and cardiovascular health in childhood. *Pediatrics*. 2008;122:198–208. doi: 10.1542/peds.2008-1349.
214. Burke LE, Styn MA, Sereika SM, Conroy MB, Ye L, Glanz K, Sevick MA, Ewing LJ. Using mHealth technology to enhance self-monitoring for weight loss: a randomized trial. *Am J Prev Med*. 2012;43:20–26. doi: 10.1016/j.amepre.2012.03.016.
215. Hopkins PN, Toth PP, Ballantyne CM, Rader DJ; National Lipid Association Expert Panel on Familial Hypercholesterolemia. Familial hypercholesterolemias: prevalence, genetics, diagnosis and screening recommendations from the National Lipid Association Expert Panel on Familial Hypercholesterolemia. *J Clin Lipidol*. 2011;5(suppl):S9–S17. doi: 10.1016/j.jacl.2011.03.452.

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Circulation

216. Jellinger PS, Smith DA, Mehta AE, Ganda O, Handelsman Y, Rodbard HW, Shepherd MD, Seibel JA; AACE Task Force for Management of Dyslipidemia and Prevention of Atherosclerosis. American Association of Clinical Endocrinologists' Guidelines for Management of Dyslipidemia and Prevention of Atherosclerosis. *Endocr Pract*. 2012;18(suppl 1):1–78.
217. American Diabetes Association. Standards of medical care in diabetes—2012. *Diabetes Care*. 2012;35(suppl 1):S11–S63.
218. Keevil JG, Cullen MW, Gangnon R, McBride PE, Stein JH. Implications of cardiac risk and low-density lipoprotein cholesterol distributions in the United States for the diagnosis and treatment of dyslipidemia: data from National Health and Nutrition Examination Survey 1999 to 2002. *Circulation*. 2007;115:1363–1370.
219. Hobbs FD, Erhardt L. Acceptance of guideline recommendations and perceived implementation of coronary heart disease prevention among primary care physicians in five European countries: the Reassessing European Attitudes about Cardiovascular Treatment (REACT) survey. *Fam Pract*. 2002;19:596–604.
220. Eaton CB, Galliher JM, McBride PE, Bonham AJ, Kappus JA, Hickner J. Family physician's knowledge, beliefs, and self-reported practice patterns regarding hyperlipidemia: a National Research Network (NRN) survey. *J Am Board Fam Med*. 2006;19:46–53.
221. Abroms LC, Windsor R, Simons-Morton B. Getting young adults to quit smoking: a formative evaluation of the X-Pack Program. *Nicotine Tob Res*. 2008;10:27–33. doi: 10.1080/14622200701767852.
222. Abroms LC, Maibach EW. The effectiveness of mass communication to change public behavior. *Annu Rev Public Health*. 2008;29:219–234. doi: 10.1146/annurev.publhealth.29.020907.090824.
223. Pignone M, Sheridan SL, Lee YZ, Kuo J, Phillips C, Mulrow C, Zeiger R. Heart to Heart: a computerized decision aid for assessment of coronary heart disease risk and the impact of risk-reduction interventions for primary prevention. *Prev Cardiol*. 2004;7:26–33.
224. Blasco A, Carmona M, Fernández-Lozano I, Salvador CH, Pascual M, Sagredo PG, Somolinos R, Muñoz A, García-López F, Escudier JM, Mingo S, Toquero J, Moñivas V, González MA, Fragua JA, López-Rodríguez F, Monteagudo JL, Alonso-Pulpón L. Evaluation of a telemedicine service for the secondary prevention of coronary artery disease. *J Cardiopulm Rehabil Prev*. 2012;32:25–31. doi: 10.1097/HCR.0b013e3182343aa7.
225. Dekkers JC, van Wier MF, Ariëns GA, Hendriksen IJ, Pronk NP, Smid T, van Mechelen W. Comparative effectiveness of lifestyle interventions on cardiovascular risk factors among a Dutch overweight working population: a randomized controlled trial. *BMC Public Health*. 2011;11:49. doi: 10.1186/1471-2458-11-49.
226. Nakajima R, Nakamura K, Takano T, Seino K, Inose T. Improvements in health by consultations using mobile videophones among participants in a community health promotion programme. *J Telemed Telecare*. 2007;13:411–415. doi: 10.1258/135763307783064403.
227. Park MJ, Kim HS, Kim KS. Cellular phone and Internet-based individual intervention on blood pressure and obesity in obese patients with hypertension. *Int J Med Inform*. 2009;78:704–710. doi: 10.1016/j.ijmedinf.2009.06.004.
228. Read E. Feasibility of the Diabetes and Technology for Increased Activity (DaTA) Study: a pilot intervention in high-risk rural adults. *J Phys Act Health*. 2014;11:118–126. doi: 10.1123/jpah.2011-0381.
229. Robroek SJ, Polinder S, Bredt FJ, Burdorf A. Cost-effectiveness of a long-term Internet-delivered worksite health promotion programme on physical activity and nutrition: a cluster randomized controlled trial. *Health Educ Res*. 2012;27:399–410. doi: 10.1093/her/cys015.
230. Stuckey M, Russell-Minda E, Read E, Munoz C, Shoemaker K, Kleinstiver P, Petrella R. Diabetes and Technology for Increased Activity (DaTA) study: results of a remote monitoring intervention for prevention of metabolic syndrome. *J Diabetes Sci Technol*. 2011;5:928–935.
231. Park MJ, Kim HS. Evaluation of mobile phone and Internet intervention on waist circumference and blood pressure in post-menopausal women with abdominal obesity. *Int J Med Inform*. 2012;81:388–394. doi: 10.1016/j.ijmedinf.2011.12.011.
232. Wilson PW, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. *Circulation*. 1998;97:1837–1847.
233. Maibach EW, Abroms LC, Marosits M. Communication and marketing as tools to cultivate the public's health: a proposed "people and places" framework. *BMC Public Health*. 2007;7:88. doi: 10.1186/1471-2458-7-88.
234. Stone NJ, Robinson JG, Lichtenstein AH, Bairey Merz CN, Blum CB, Eckel RH, Goldberg AC, Gordon D, Levy D, Lloyd-Jones DM, McBride P, Schwartz JS, Shero ST, Smith SC Jr, Watson K, Wilson PWF. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines [published correction appears in *Circulation*. 2014;129(suppl 2):S46]. *Circulation*. 2014;129(suppl 2):S1–45. doi: 10.1161/01.cir.0000437738.63853.7a.
235. Abroms LC, Fagan P, Eisenberg ME, Lee HS, Remba N, Sorensen G. The STRENGTH Ezine: an application of e-mail for health promotion in adolescent girls. *Am J Health Promot*. 2004;19:28–32.
236. Cho JH, Kwon HS, Kim HS, Oh JA, Yoon KH. Effects on diabetes management of a health-care provider mediated, remote coaching system via a PDA-type glucometer and the Internet. *J Telemed Telecare*. 2011;17:365–370. doi: 10.1258/jtt.2011.100913.
237. Brath H, Morak J, Kästenbauer T, Modre-Osprian R, Strohner-Kästenbauer H, Schwarz M, Kort W, Schreier G. Mobile health (mHealth) based medication adherence measurement: a pilot trial using electronic blisters in diabetes patients. *Br J Clin Pharmacol*. 2013;76(suppl 1):47–55. doi: 10.1111/bcp.12184.
238. Kang JY, Cho SW, Sung SH, Park YK, Paek YM, Choi TI. Effect of a continuous diabetes lifestyle intervention program on male workers in Korea. *Diabetes Res Clin Pract*. 2010;90:26–33. doi: 10.1016/j.diabres.2010.06.006.
239. Ralston JD, Hirsch IB, Hoath J, Mullen M, Cheadle A, Goldberg HI. Web-based collaborative care for type 2 diabetes: a pilot randomized trial. *Diabetes Care*. 2009;32:234–239. doi: 10.2337/dc08-1220.
240. Chow CK, Redfern J, Thiagalingam A, Jan S, Whittaker R, Hackett M, Graves N, Mooney J, Hillis GS. Design and rationale of the Tobacco, Exercise and Diet Messages (TEXT ME) trial of a text message-based intervention for ongoing prevention of cardiovascular disease in people with coronary disease: a randomised controlled trial protocol. *BMJ Open*. 2012;2:e000606. doi: 10.1136/bmjopen-2011-000606.
241. Farzanfar R, Finkelstein J, Friedman RH. Testing the usability of two automated home-based patient-management systems. *J Med Syst*. 2004;28:143–153.
242. Oncescu V, Mancuso M, Erickson D. Cholesterol testing on a smartphone. *Lab Chip*. 2014;14:759–763. doi: 10.1039/c3lc51194d.
243. Goessens BM, Visseren FL, de Nooijer J, van den Borne HW, Algra A, Wierdsma J, van der Graaf Y; SMART Study Group. A pilot-study to identify the feasibility of an Internet-based coaching programme for changing the vascular risk profile of high-risk patients. *Patient Educ Couns*. 2008;73:67–72. doi: 10.1016/j.pec.2008.06.004.
244. Lester WT, Grant RW, Barnett GO, Chueh HC. Randomized controlled trial of an informatics-based intervention to increase statin prescription for secondary prevention of coronary disease. *J Gen Intern Med*. 2006;21:22–29. doi: 10.1111/j.1525-1497.2005.00268.x.
245. Redfern J, Usherwood T, Harris MF, Rodgers A, Hayman N, Panaretto K, Chow C, Lau AY, Neubeck L, Coorey G, Hersch F, Heeley E, Patel A, Jan S, Zwar N, Peiris D. A randomised controlled trial of a consumer-focused e-health strategy for cardiovascular risk management in primary care: the Consumer Navigation of Electronic Cardiovascular Tools (CONNECT) study protocol. *BMJ Open*. 2014;4:e004523. doi: 10.1136/bmjopen-2013-004523.
246. DiFilippo KN, Huang WH, Andrade JE, Chapman-Novakofski KM. The use of mobile apps to improve nutrition outcomes: a systematic literature review [published online ahead of print February 12, 2015]. *J Telemed Telecare*. doi: 10.1177/1357633X15572203. http://jtt.sagepub.com/content/early/2015/02/12/1357633X15572203.long. Accessed July 23, 2015.
247. Arnhold M, Quade M, Kirch W. Mobile applications for diabetics: a systematic review and expert-based usability evaluation considering the special requirements of diabetes patients age 50 years or older. *J Med Internet Res*. 2014;16:e104. doi: 10.2196/jmir.2968.
248. Choi J, Noh GY, Park DJ. Smoking cessation apps for smartphones: content analysis with the self-determination theory. *J Med Internet Res*. 2014;16:e44. doi: 10.2196/jmir.3061.
249. Husain I, Spence D. Can healthy people benefit from health apps? *BMJ*. 2015;350:h1887. doi: 10.1136/bmj.h1887.
250. Kuehn BM. Is there an app to solve app overload? *JAMA*. 2015;313:1405–1407. doi: 10.1001/jama.2015.2381.
251. Nahum-Shani I, Qian M, Almirall D, Pelham WE, Gnagy B, Fabiano GA, Waxmonsky JG, Yu J, Murphy SA. Experimental design and primary data analysis methods for comparing adaptive interventions. *Psychol Methods*. 2012;17:457–477. doi: 10.1037/a0029372.
252. Collins LM, Murphy SA, Bierman KL. A conceptual framework for adaptive preventive interventions. *Prev Sci*. 2004;5:185–196.

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253. Pellegrini CA, Steglitz J, Hoffman SA. e-Health intervention development: a synopsis and comment on "What Design Features are Used in Effective e-Health Interventions? A Review Using Techniques From Critical Interpretive Synthesis". *Transl Behav Med*. 2014;4:342–345. doi: 10.1007/s13142-014-0283-y.
254. Merriel SW, Andrews V, Salisbury C. Telehealth interventions for primary prevention of cardiovascular disease: a systematic review and meta-analysis. *Prev Med*. 2014;64:88–95. doi: 10.1016/j.ypmed.2014.04.001.
255. Free C, Phillips G, Galli L, Watson L, Felix L, Edwards P, Patel V, Haines A. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS Med*. 2013;10:e1001362. doi: 10.1371/journal.pmed.1001362.

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Current Science on Consumer Use of Mobile Health for Cardiovascular Disease Prevention: A Scientific Statement From the American Heart Association

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