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The Use of Behavior Change Techniques and Theory in Technologies for Cardiovascular Disease Prevention and Treatment in Adults: A Comprehensive Review

Sandra J Winter, PhD, MHA [Research Associate],

Stanford Prevention Research Center, Stanford University School of Medicine, Palo Alto, CA

Jylana L Sheats, PhD, MPH [Research Associate], and

Stanford Prevention Research Center, Stanford University School of Medicine, Palo Alto, CA

Abby C King, PhD [Professor of & Health Research & Policy and of Medicine]

Stanford University School of Medicine, Palo Alto, CA

Abstract

This review examined the use of health behavior change techniques and theory in technology-enabled interventions targeting risk factors and indicators for cardiovascular disease (CVD) prevention and treatment. Articles targeting physical activity, weight loss, smoking cessation and management of hypertension, lipids and blood glucose were sourced from PubMed (November 2010-2015) and coded for use of 1) technology, 2) health behavior change techniques (using the CALO-RE taxonomy), and 3) health behavior theories. Of the 984 articles reviewed, 304 were relevant (240=intervention, 64=review). Twenty-two different technologies were used ($M=1.45$, $SD=+/-0.719$). The most frequently used behavior change techniques were self-monitoring and feedback on performance ($M=5.4$, $SD=+/-2.9$). Half (52%) of the intervention studies named a theory/model - most frequently Social Cognitive Theory, the Trans-theoretical Model, and the Theory of Planned Behavior/Reasoned Action. To optimize technology-enabled interventions targeting CVD risk factors, integrated behavior change theories that incorporate a variety of evidence-based health behavior change techniques are needed.

Keywords

Behavior change techniques; behavioral theory; cardiovascular disease prevention and treatment; health promotion technologies

Modifiable health behaviors including tobacco use, physical inactivity, and poor diet contribute significantly to cardiovascular (CV) disease (CVD) morbidity and mortality [1]. Achieving population-wide, sustained improvements in these behaviors remains difficult.

Corresponding author: Suite 100, 1070 Arastradero Road, Palo Alto, CA, 94305-1334, Telephone: 859-229-7459, sjwinter@stanford.edu.

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The use of health information technologies holds great promise for improving CV-related health worldwide [2] as they are potentially cost-effective, broadly accessible, adaptive, and have the ability to operate in real-world and real-time circumstances. Examples of health information technologies include mobile phones, wearable sensors, telehealth devices and applications, interactive voice response (IVR) systems, gaming consoles, virtual reality, and interactive Web 2.0 platforms. Recent findings from the Pew Research Center indicate that technology use among adults in the United States (U.S.) is substantial [3] with high levels of cellphone (including smartphone) and computer ownership: for example, 92% of U.S. adults currently own a cellphone or smartphone. Notably, in the last four years the number of adults owning smartphones has nearly doubled—up from 35% in 2011 to 68% in 2015. In addition, three-quarters (73%) of U.S. adults own a desktop or laptop computer. With numerous advances in technology occurring at a rapid rate, smartphones are being transformed into all-purpose devices that can perform functions of a computer and other devices such as e-readers, MP3 players, games, etc. Tablet computers, which are owned by almost half (45%) of U.S. adults, have many functions in common with smartphones. While use is generally lower among older adults (78%), overall use is common among all major demographics in the U.S.—including racial/ethnic minorities [3]. Although the development of technologies for CVD prevention and treatment are increasing, there are recognized challenges that remain to be addressed. In the American Heart Association's (AHA) Scientific Statement “Current Science on Consumer Use of Mobile Health for Cardiovascular Disease Prevention”[4], one of the recommendations for future research highlighted the need for the development of technologies that are based on proven behavioral techniques and theories. The aim of this paper is to provide a comprehensive review of the current use of behavior change techniques and theories in technology-enabled approaches for CVD prevention and treatment.

Methods

Search Terms

A search of the literature on technology-enabled approaches for CVD prevention and treatment was conducted using the PubMed database in November 2015. The search began with a combination of terms in the following three categories: 1) health behaviors and indicators, 2) technologies, and 3) behavioral theories (**Table 1**). The health behaviors and relevant indicators were congruent with the key cardiovascular health metrics defined by the AHA in 2010 [5] and included the following: physical activity (PA), weight management, tobacco use, blood glucose, blood pressure and lipids. To gain the broadest understanding of the current state of the science in this field, a comprehensive array of terms was included for technologies, including mobile, social media, wearables, and other Internet-based terms. Similarly, a comprehensive array of terms was used to search for behavior and behavior change theories. References from articles meeting the inclusion criteria for this review were subsequently reviewed to identify additional relevant articles meeting the search inclusion criteria (**Table 1**). Free English language full-text articles produced between November 2010 and November 2015 were included in this review.

Inclusion Criteria

The Article Review Diagram is displayed in **Figure 1**. Articles describing health behavior change interventions targeting CVD prevention and treatment among adults were included and, because of the substantial overlap of the risk factors for diabetes mellitus and CVD, articles describing diabetes prevention and treatment were also included. Exclusion criteria included articles that described observational, focus group, computer modeling, measurement validation or economic evaluation studies; expert opinion or conceptual articles; protocol papers that described study methodology for planned studies that did not include results; articles targeting other conditions, such as rheumatoid arthritis, macular degeneration or multiple sclerosis; and articles describing interventions targeting children or adolescents.

Data Extraction

The following data were extracted from each relevant article: year of publication, country of authorship, type of technology, health risk factor(s) and/or indicator(s) targeted, behavior change techniques utilized, and behavior change theory named. The behavior change techniques were categorized using the CALO-RE behavior change taxonomy created by Michie, et al. [6].

Data Synthesis

Due to the comprehensive nature of this review across various health-promoting technologies as well as health behavior risk factors and indicators, a narrative approach was utilized to synthesize the data as opposed to conducting a meta-analysis. The assessment of intervention quality and/or effectiveness for each article was beyond the scope of this review.

RESULTS

A total of 984 articles published between November 2010 and November 2015 were identified using the PubMed search criteria (**Figure 1**). Of these, 680 articles (69.1%) were excluded because they were not relevant in regard to the implementation of technology-based interventions for adults focused on the prevention or treatment of CVD.

Assessment of Intervention Articles

An assessment of the 240 full-text intervention articles meeting the study inclusion criteria revealed that they were conducted by researchers in 23 countries, with the majority (n=77, 60%) taking place in the United States (U.S.), and also from the United Kingdom (n=13, 8.3%), the Netherlands (n=12, 7.5%) and Australia (n=9, 5.8%)

Cardiovascular Health Risk Behaviors and Indicators

Descriptive analyses indicated that the following CVD risk behaviors and indicators were addressed by the studies under review (with some studies contributing more than one risk behavior or indicator): PA (46%), weight loss (38%), healthy eating (29%), tobacco cessation (26%), health promotion (14%), blood pressure (12%), glucose monitoring (9%) lipid monitoring (5%), and sitting (2.5%). Additional behaviors included self-management

(15%), reducing alcohol consumption (6%), stress management (2%), reducing risks (2%), and healthy coping and support (1%).

Use of Technology in CVD Prevention and Treatment Interventions

Twenty-two different types of technologies were used across the 240 studies. Two-thirds (66%) of the studies used one type of technology—with the remainder using up to five different types of technologies ($M=1.45$, $SD= \pm 0.719$). Among all studies, the most frequently used technologies were Internet-based program delivery (i.e. websites) ($n=132$, 55%), activity monitors and sensors ($n=39$, 16%) and mobile/smartphones ($n=35$, 15%). Less frequently used technologies included the use of text messages ($n=17$, 7%), gaming consoles ($n=11$, 4.6%) and virtual reality ($n=10$, 4.2%). Among intervention studies focused on healthy eating and physical activity, using the Internet (healthy eating, $n=47$; PA, $n=65$), mobile/smartphones (healthy eating, $n=10$; physical activity, $n=16$), and activity monitors and sensors (healthy eating, $n=8$; PA, $n=20$), were the most frequently used types of technologies. The most frequently used types of technologies for interventions focused on changing tobacco-related behaviors were the Internet/websites ($n=38$) and mobile/smartphone apps ($n=8$). Mobile/smartphone apps ($n=9$) and email ($n=2$) were most frequently used for lipid monitoring, whereas mobile/smartphones ($n=9$), telephones (LAN line) ($n=9$) and PA monitors and sensors ($n=7$) were used most frequently for glucose monitoring. Finally, for blood pressure (BP), the activity monitors and sensors ($n=15$), telehealth methods (i.e. the use of Bluetooth BP monitors and weighing scales) ($n=12$), and the Internet/websites ($n=11$) were the most frequently used technologies among the studies reviewed.

Behavior Change Techniques Used in Technology-Enabled CVD Prevention and Treatment Interventions

Between one and 18 of the 40 different behavior change techniques described in the CALORE taxonomy ($M=5.4$, $SD= \pm 2.9$) were used in the studies reviewed (**Figure 2**). The vast majority of studies used more than one type of behavior change technique ($n=219$, 91%) with only 9% ($n=21$) using only one. As can be seen in **Figure 2**, the behavior change techniques most frequently implemented included the following: self-monitoring of the behavior ($n=140$, 58.3%), providing feedback on performance ($n=109$, 45%), goal setting (behavior) ($n=100$, 42%), planning social support/social change ($n=97$, 40%), providing information on the consequences associated with the behavior in general ($n=94$, 39%), prompting self-monitoring of the behavioral outcome ($n=94$, 39%), providing information on the consequences of behavior specifically for the individual ($n=86$, 36%) and providing information on how to perform the behavior ($n=78$, 33%). Behavior change techniques less frequently implemented included the following: goal setting related to the health outcome ($n=73$, 30%), barrier identification and problem solving ($n=58$, 24%), action planning ($n=49$, 20%), and review of behavioral goals ($n=36$, 15%). Follow-up prompts, fear arousal, prompting of self-talk around intervention targets, and stimulating anticipation of *future* rewards were not utilized in the articles reviewed. **Figure 3** displays the behavior change techniques used for the behaviors of interest. Self-monitoring of behavior was the most frequently used behavior change technique for healthy eating ($n= 48$), PA ($n= 65$), and health promotion/lifestyle changes ($n= 19$). For tobacco cessation and lipid monitoring, the

most frequently used behavior change techniques were providing information about the consequences of the behavior to the individual (tobacco cessation, n= 30), or in general (lipid monitoring, n= 8). For the management of glucose (n=16) and BP (n=21), the most frequently used behavior change techniques were self-monitoring of the outcome.

Behavior Change Theories Used in Technology-Enabled CVD Prevention and Treatment Interventions

Just over half (52%) of the intervention studies reviewed explicitly named at least one cognitive or behavioral theory and/or model—with the maximum number of theories named being six. The most frequently named theories were classic behavior change theories such as Social Cognitive Theory (n=52) [7], Stages of Change/Trans-theoretical Model (n=23) [8], and the Theory of Planned Behavior/Theory of Reasoned Action (n=15) [9-12]. Social Cognitive Theory was the most frequently used theory named in studies focused on weight loss (n=27), PA (n=24), healthy eating (n=22), tobacco (n=10), and glucose monitoring (n=2). Both Social Cognitive Theory and the Social Ecological Model were utilized most often for lipid monitoring (n=2; n=2) and BP (n=2; n=2); whereas there was no definitive theory or model that was used most often for sitting behaviors. Less frequently used models included the Integrated Behavior Change Model [13] and the Prime Theory of Motivation[14].

Assessment of Review Articles

Sixty-four relevant systematic review articles were identified via the PubMed search as well. These articles focused on five primary categories: 1) weight loss and obesity prevention (n=18, 28%), 2) health behavior/lifestyle change (n=15, 23%), 3) PA promotion (n=13, 20%), 4) self-management of health behaviors (n=11, 17%), and 5) tobacco cessation/reduction of harmful alcohol consumption (n=7, 12%). The general conclusion that emerged from these reviews is that the success of technology-driven behavioral risk interventions is still quite mixed, and thus further research of good methodological quality is required. Most noted that the pace of technological innovation in the field of CVD prevention and treatment is rapid and not currently matched by the pace of research. Research that tests which components of interventions work best for different population groups under varying circumstances has been consistently noted to be particularly necessary.

Weight Loss/Management Reviews

Recurring themes in the reviews of weight loss/management studies included the finding that social support, social media, real-time feedback, and greater engagement with intervention technologies contribute to more successful outcomes. However, compared to face-to-face weight loss interventions, technology-mediated interventions generally have smaller effect sizes and are suggested as useful complementary intervention components to more intensive existing programs. Concerns that need to be addressed include poorly designed study methodologies, poor treatment adherence, low fidelity to program protocols, and lack of evidence-based content and behavior change techniques in weight loss applications. Advantages of technology-enabled weight loss interventions include being able

to gather objective, “just-in-time” data in real world settings, which reduces recall bias and allows for the ability to provide users with timely feedback.

Health Behavior and Lifestyle Change Reviews

The articles focusing broadly on health behavior and lifestyle change included a variety of technologies such as computer-tailored and web-based interventions, social media, text messaging, videos, IVR systems, personal digital assistants, embodied conversational agents, mobile apps, and wearable sensors and monitors. Themes of these reviews included the following: small effect sizes—especially for interventions that were not dynamically tailored to participants; lack of sustainable health behavior change improvements over time; difficulty recruiting and retaining participants for technology-enabled interventions; inadequate use and harnessing of the power of health improvement technology methods and algorithms; inadequate attention to the interaction between technology and individual needs; inadequate use of behavior change theory; lack of multi-disciplinary, including partnerships with private-sector health information technology developers; the benefit of incorporating multiple modes of delivery; concerns regarding privacy; and lack of access to technology that may discriminate against marginalized populations.

Physical Activity Reviews

As noted in reviews of other health behaviors, technology-enabled interventions have resulted in mixed success. Poor quality websites and lack of evidence-based content and behavior change techniques were noted.

Self Management Reviews

A general theme of the review articles that focused on self-management techniques for cardiovascular prevention and treatment suggest that more interventions should include evidence-based content and be grounded in behavior change theory. Other recommendations proposed are that website quality should be improved and research should be conducted to combat the problem of user attrition.

Tobacco Cessation and Harmful Alcohol Reduction Reviews

The articles that reviewed the use of technology (web-based interventions, text messaging, social media) to reduce tobacco and/or alcohol use have shown limited success. Possible benefits of technology-enabled tobacco cessation and alcohol reduction interventions that have been noted in current reviews include enhanced accessibility, cost effectiveness, sustainability, and reach. Methodological flaws discussed in the reviews included poor adherence to cessation treatment guidelines, flawed statistical methodology, and lack of use of control groups.

Discussion

This comprehensive review indicates that behavior change techniques and theories are being used to varying degrees in an array of technology-enabled interventions targeting modifiable

risk factors for CVD. With the current level and variety of technology in use among all demographics of U.S. adults, using technology to promote health is increasingly appropriate and indicated. In this review, Internet intervention platforms and mobile phone apps were the most frequently used technologies, but interesting work is also being conducted with newer technologies including the following: *virtual reality*, which is being used, for example, to examine cue reactivity in tobacco use [15-18], improve mobility in stroke patients [19, 20], and promote PA [21]; *gaming* to increase engagement and the dose-response of interventions designed to increase PA and reduce weight [22-26]; *alternate world reality gaming* to increase PA and reduce weight [27, 28]; *avatars* to promote PA [29, 30]; *Embodied Conversational Agents* (virtual coaches) to promote PA and increase fruit and vegetable intake [31, 32]; and *social media* for increasing engagement and social support [33-37].

Only about one-third of the possible 40 different behavioral change techniques that have been systematically categorized in the behavioral health literature [6] were consistently used in the articles included in this review, with self monitoring of the behavior or the outcome, goal setting, social support, providing feedback and providing information about the consequences of the behavior being the most utilized. Technology-enabled interventions could benefit from more thoughtful intervention component designs that are adaptive, as well as theory and evidence-based. Potential methods to improve intervention design in this area include the following: Multiphase Optimization Strategies (MOST), which uses a screening, refining, and confirming phase to determine the optimal utilization and timing of intervention components[38]; Sequential Multiple Assignment Randomized Trial (SMART), which represents an experimental approach for determining the optimal sequencing, frequency, timing, and appropriateness of intervention components (an approach which is particularly suited to designing time-varying adaptive interventions) [38]; and, Behavioral Science-informed User Experience Design (BSUED), which designs interventions informed from the outset by the user-experience, combined with theory and evidence-based behavioral science components[39].

Notably, behavior change theories and models have been used for decades to provide generalizable, organizing frameworks to help researchers better understand the complexities and inter-relationships of health behavior constructs. However, the considerable variation in effects described in this review [40-42] may potentially be attributed, at least in part, to the inadequate or reduced use of health behavior change theory in technology-enabled interventions [43, 44]. In the current review about half (52%) of the articles explicitly named a behavior change theory or model. To advance science in the growing field of research focused on the development and implementation of technologies to support health behavior change, theories and models may need to be re-conceptualized to accommodate the opportunities and challenges associated with technology applications [45]. For example, dynamical systems modeling may facilitate the design of interventions that can accommodate real-time, time-sensitive data in an interactive and adaptive manner to achieve lasting behavior change and improved health outcomes [46]. In addition, theoretical models that explicitly span multiple levels of influence and subsequently inform multi-level solutions with sustainable and broad-reaching population-wide effects are sorely needed [47]. Developing new theories and models should be done thoughtfully, however: a recent network analysis of the connections between behavior change theories identified 83 theories,

yet many had redundancies with other theories [48]. The authors suggest that this may create confusion and undermine scientific progress. One possible strategy to develop interventions that use integrated theories is the Theoretical Domains Framework. This framework is guided by a 4-step process to identify: 1) the target population, 2) the most appropriate theoretical framework to address the presumed barriers and enablers to change, 3) the appropriate behavior change techniques to overcome the barriers and enhance the enablers, and 4) the most appropriate evaluation methodology.[49]

Finally, it is clear that the current demand for technology-enabled applications that address the modifiable risk behaviors for CVD prevention and treatment are substantial and increasing. While technology development, fueled by underlying commercial interests, is expanding rapidly, the ability of research to keep up with its development may be hampered by current funding processes and mechanisms. Changes to the current funding system to facilitate rapid and adequate funding of novel technology studies are needed.

Strengths and Limitations

Strengths of this review include the use of a more comprehensive approach that incorporates multiple health behaviors and risk indicators relevant to CVD as well as incorporating an extensive array of health improving technologies. In addition, this review used a systematic method for coding specific behavior change techniques as well as reporting on the use of behavior change theories. A limitation of this review is that despite the research team's careful and systematic methods to identify all relevant behavior change techniques, it is possible that some were not included in this review.

Conclusion

There is tremendous potential for the use of technology-enabled interventions to improve modifiable health behaviors associated with CVD. To optimize these interventions, integrated behavior change theories that incorporate a variety of evidence-based health behavior change techniques are needed. In addition, continued efforts to better understand what has been called “the whiches conundrum” are strongly indicated, i.e., which behavioral techniques delivered through which technology channels should be utilized for which targeted behaviors and outcomes and for which population segments. Only through gaining a better understanding of such targeting activities can the full potential of technology-enabled interventions in the CVD prevention and treatment area be realized in a resource efficient way.

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Abbreviations

AHA	American Heart Association
BP	Blood pressure
CV	Cardiovascular
CVD	Cardiovascular disease
IVR	Interactive voice response
PA	Physical activity
U.S.	United States

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Figure 1.
Article Review Diagram

Figure 2.
Frequency of Use of Behavior Change Techniques in Technology-Enabled CVD Prevention and Treatment Interventions

Figure 3.
Frequency of Use of Behavior Change Techniques Used in Technology-Enabled Cardiovascular Disease Prevention and Treatment Interventions by Health Behavior

Table 1

Search terms for comprehensive review of the use of behavior change theory in cardiovascular prevention and treatment

Health Behaviors and Indicators	Technologies	Behavioral Theories
<u>Physical Activity</u> : physical activity, exercise, physical inactivity, sedentary, sitting. <u>Weight loss</u> : weight loss, weight reduction, obesity <u>Tobacco use</u> : tobacco use, tobacco cessation, smoking, smokeless tobacco <u>Health indicators</u> : blood pressure, hypertension, glucose, blood sugar, cholesterol, lipids	Social media, Twitter, Facebook, cell phone, smartphone, mobile phone, mobile applications, apps, text messaging, mobile health, technology, telemedicine, web-based, electronic mail, e-mail, Internet, wearable, monitoring sensors, GPS, interactive voice response, embodied conversational agent, virtual, electronic tablet, tablet-based, computers, handheld, digital health, eHealth, on-line systems, software, multimedia	Behavior, behavioral, behavior therapy, behavior change theory, health belief model, trans theoretical model, theory of planned behavior, precaution adoption process model, social cognitive theory, social influence theory, social ecological model, motivational frameworks, PRIME theory, self determination theory, operant conditioning, social support, theory of reasoned action, stages of change, social norms, social learning, diffusion of innovation, reasoned action approach, integrative model