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ORIGINAL ARTICLE

Digital Health Interventions for the Prevention of Cardiovascular Disease: A Systematic Review and Meta-analysis

R. Jay Widmer, MD, PhD; Nerissa M. Collins, MD; C. Scott Collins, MD; Colin P. West, MD, PhD; Lilach O. Lerman, MD, PhD; and Amir Lerman, MD

Abstract

Objective: To assess the potential benefit of digital health interventions (DHIs) on cardiovascular disease (CVD) outcomes (CVD events, all-cause mortality, hospitalizations) and risk factors compared with non-DHIs.

Patients and Methods: We conducted a systematic search of PubMed, MEDLINE, EMBASE, Web of Science, Ovid, CINHAL, ERIC, PsychINFO, Cochrane, and Cochrane Central Register of Controlled Trials for articles published from January 1, 1990, through January 21, 2014. Included studies examined any element of DHI (telemedicine, Web-based strategies, e-mail, mobile phones, mobile applications, text messaging, and monitoring sensors) and CVD outcomes or risk factors. Two reviewers independently evaluated study quality utilizing a modified version of the Cochrane Collaboration risk assessment tool. Authors extracted CVD outcomes and risk factors for CVD such as weight, body mass index, blood pressure, and lipid levels from 51 full-text articles that met validity and inclusion criteria.

Results: Digital health interventions significantly reduced CVD outcomes (relative risk, 0.61; 95% CI, 0.46-0.80; $P<.001$; $I^2=22\%$). Concomitant reductions in weight (−2.77 lb [95% CI, −4.49 to −1.05 lb]; $P<.002$; $I^2=97\%$) and body mass index (−0.17 kg/m^2 [95% CI, −0.32 kg/m^2 to −0.01 kg/m^2]; $P=.03$; $I^2=97\%$) but not blood pressure (−1.18 mm Hg [95% CI, −2.93 mm Hg to 0.57 mm Hg]; $P=.19$; $I^2=100\%$) were found in these DHI trials compared with usual care. In the 6 studies reporting Framingham risk score, 10-year risk percentages were also significantly improved (−1.24%; 95% CI, −1.73% to −0.76%; $P<.001$; $I^2=94\%$). Results were limited by heterogeneity not fully explained by study population (primary or secondary prevention) or DHI modality.

Conclusion: Overall, these aggregations of data provide evidence that DHIs can reduce CVD outcomes and have a positive impact on risk factors for CVD.

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Cardiovascular disease (CVD) is the primary cause of morbidity and mortality and is associated with markedly increasing health care costs in the United States.[1] Approximately 1 in 3 deaths can be attributed to CVD,[1,2] and more than 90% of CVD morbidity and mortality can be attributed to preventable risk factors.[3] According to 2012 statistics, poor diet, smoking, and lack of physical activity continue to account for an overwhelming majority of CVDs and death,[4] with the cost of CVD in the United States approaching $200 billion per year.[1] Moreover, the average hospitalization for acute coronary syndrome is estimated to cost roughly $20,000, with repeated events costing up to 2 and 3 times the original amount.[5] Clearly, better interventions to improve CVD prevention, both primary and secondary, are needed.

Internet and smartphone use has grown exponentially in the past decade, opening up the possibility that these increasingly prevalent technological tools could improve health. Digital health interventions (DHIs), including such modalities as telemedicine, Web-based strategies, e-mail, mobile phones, mobile applications, text messaging, and monitoring sensors, are the most recent iteration of an effort to shift health care burden outside the walls of medical institutions and improve individualized care through positive behavior change theory.[6] Although previous studies have suggested benefits of DHIs in focused areas such as smoking cessation,[7]

From the Division of Cardiovascular Diseases (R.J.W., A.L.), Division of General Internal Medicine (N.M.C., C.S.C., C.P.W.), Division of Biomedical Statistics and Informatics (C.P.W.), and Division of Nephrology and Hypertension (L.O.L.), Mayo Clinic, Rochester, MN.

behavior patterns,[8] physical activity,[9] hemoglobin A_{1c},[10] blood pressure,[11] and weight loss,[12] evidence concerning the benefit of DHIs on CVD risk factors, let alone CVD outcomes such as CVD events, hospitalizations, and all-cause mortality, is lacking. With nearly 50,000 health care–related apps now available for download[13] and numerous Internet-based DHI solutions available, the benefit of DHIs on CVD prevention and outcomes, both primary and secondary, merits reexamination.

The purpose of this systematic review and meta-analysis was to inclusively review randomized controlled trials (RCTs) and cohort studies incorporating DHIs for the prevention of CVD outcomes (CVD events including myocardial infarction, stroke, revascularization, hospitalizations, and all-cause mortality) and modification of risk factors for CVD such as weight, body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared), blood pressure, cholesterol and glucose levels, and Framingham risk score (FRS). Our aim was to establish the potential benefit of DHIs on both primary and secondary CVD prevention and identify future needs in DHI and CVD research.

PATIENTS AND METHODS

Data Sources and Searches

This systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[14] We included all RCTs and observational/cohort studies published between January 1, 1990, and January 21, 2014, that examined any element of DHI (telemedicine, Web-based strategies, e-mail, mobile phones, mobile applications, text messaging, and monitoring sensors) and impact on CVD. We intentionally and broadly included any studies of adult patients seeking CVD prevention to present a comprehensive overview of DHI studies analyzing CVD outcomes (CVD events, hospitalizations, or all-cause mortality) and modification of risk factors for CVD such as weight, BMI, blood pressure, cholesterol and glucose levels, and FRS regardless of type of health care professional or health care setting. Control interventions included usual care following standard guidelines and could involve non-DHIs (such as paper instructions or telephone calls) or no active intervention beyond usual care. We excluded studies in which the intervention lasted less than a month in order to assess long-term impact and sustainability, studies that did not report any CVD risk factors, redundant studies that were repeated in the literature without new data presented, protocol manuscripts, reviews, studies including only usability or adherence data, pediatric studies, and studies in which the intervention involved the health care professional rather than the patient.

Our search strategy was performed with the assistance of a medical librarian and included the PubMed, MEDLINE, EMBASE, Web of Science, Ovid, CINAHL, ERIC, PsychINFO, Cochrane, and Cochrane Central Register of Controlled Trials databases over the specified dates. We included the following search terms: *mobile health*, *mobile*, *mhealth*, *digital health*, *eHealth*, *internet*, *telemedicine*, *web*, *smartphone*, *cardiovascular*, *cardiac*, *prevention*, *outcomes*, *mortality*, *morbidity*, *event*, *Framingham*, *blood pressure*, *weight*, *BMI*, *waist circumference*, *glucose*, *lipids*, *cholesterol*, *smoking*, *tobacco*, *quality of life*, *emergency department*, *visits*, *hospitalizations*, *rehospitalizations*, *office visits*, *phone calls*, *cost*, *cost of care*, and *ROI*. This strategy identified 574 relevant abstracts, and an additional 14 references were identified through bibliography searches and personal contacts (Figure 1). Most articles were in English, and those in Spanish, Polish, and German were translated for review.

Study Selection

Two reviewers (R.J.W., N.M.C.) assessed each of the identified abstracts. Full-text versions of potentially eligible studies, categorized for inclusion by either reviewer, were requested (n=73). The 2 reviewers worked independently to evaluate the full-text reports for study inclusion, and disagreements were reconciled by consensus. Agreement on study inclusion was high, with $\kappa = 0.92$.

Data Extraction and Quality Assessment

Extracted data included study participant demographic characteristics (age, sex, previous Internet use, education level, socioeconomic status, race, comorbidities, and baseline markers of CVD), the DHI they received (frequency, type, and duration), and the control intervention. The DHIs

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