Circulation: Cardiovascular Quality and Outcomes

AHA SCIENTIFIC STATEMENT

Harnessing Mobile Health Technology for Secondary Cardiovascular Disease Prevention in Older Adults

A Scientific Statement From the American Heart Association

ABSTRACT: Secondary prevention of cardiovascular disease (CVD), the leading cause of morbidity and mortality, is critical to improving health outcomes and quality of life in our aging population. As mobile health (mHealth) technology gains universal leverage and popularity, it is becoming more user-friendly for older adults and an adjunct to manage CVD risk and improve overall cardiovascular health. With the rapid advances in mHealth technology and increasing technological engagement of older adults, a comprehensive understanding of the current literature and knowledge of gaps and barriers surrounding the impact of mHealth on secondary CVD prevention is essential. After a systematic review of the literature, 26 studies that used mHealth for secondary CVD prevention focusing on lifestyle behavior change and medication adherence in cohorts with a mean age of ≥60 years were identified. Improvements in health behaviors and medication adherence were observed, particularly when there was a short message service (ie, texting) component involved. Although mobile technologies are becoming more mainstream and are starting to blend more seamlessly with standard health care, there are still distinct barriers that limit implementation particularly in older adults, including affordability, usability, privacy, and security issues. Furthermore, studies on the type of mHealth that is the most effective for older adults with longer study duration are essential as the field continues to grow. As our population ages, identifying and implementing effective, widely accepted, cost-effective, and time-efficient mHealth interventions to improve CVD health in a vulnerable demographic group should be a top health priority.

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Health technology is becoming ubiquitous in the United States and worldwide. Using the internet and other information and communication technologies to provide health services and deliver health information, commonly referred to as electronic health,[1–3] has become mainstream in health care, even among older adults.[4] One of the most popular and rapidly expanding electronic health approaches is mobile health (mHealth).[5] Many definitions for mHealth exist (Table 1), but to date, no standardized definition has been established.[5] Consistent with the World Health Organization's definition, mHealth is defined in this statement as "the use of mobile and wireless technologies to support the achievement of health objectives."[5] This includes voice and short messaging service (SMS; ie, text messaging), global positioning system, and Bluetooth technologies, as well as wearable garments or accessories that provide physiological monitoring. However, this excludes telemedicine, which is a separate type of electronic health defined by Oxford as "the remote diagnosis and treatment of patients by means of telecommunications technology" (eg, remote cardiac rehabilitation).[15] Although mHealth has been a powerful approach to educate and engage older adults in the primary prevention of cardiovascular disease (CVD),[16] little is known about its use for secondary CVD prevention, specifically among adults ≥60 years of age, the demographic group at the highest risk of CVD events.[17] As technology evolves, it is critical to use mHealth technologies to further prevent CVD progression and additional major adverse cardiac events in older adults with established disease.

CVD, defined in this statement as coronary artery disease, acute coronary syndrome, heart failure, congenital heart disease, cerebrovascular disease, valvular disease, peripheral artery disease, or atrial fibrillation, is the leading cause of mortality in the United States.[17] Strategies to slow the progression of CVD are crucial because individuals who have had a major cardiac event have a 20-fold increase in risk of a future cardiac event compared with individuals without CVD.[18] Despite major advances in preventive care, increasing age remains the most prominent nonmodifiable risk factor for the development and progression of CVD; two-thirds of all patients with CVD are >60 years of age.[17] Furthermore, the global population of adults ≥60 years of age is the fastest growing demographic and expected to reach nearly 2.1 billion by 2050.[19] mHealth interventions targeting older adults with CVD have the potential to provide significant benefits for this disproportionate segment of the population.

Despite perceived barriers of technology adoption among older adults, 80% of adults >65 years of age own a cell phone, and 67% use the internet.[20] Furthermore, Americans ≥60 years of age are spending more time in front of screens than they did a decade ago, with more than half of their daily leisure time (4 hours 16 minutes) being spent in front of a television, computer, tablet, or other electronic device.[20] Given the advances in mHealth technology and the increased engagement of older adults with mobile technologies, mHealth is a tool that can be used for continuous health monitoring to support proven efficacious therapeutic lifestyle changes and prevent disease progression among older adults with CVD. mHealth technologies can be used for health promotion to engage older adults in self-managing selected health parameters known to increase CVD risk.[21] Real-time feedback via mHealth can facilitate and encourage lifestyle behavior change (eg, physical activity and dietary modification), medication adherence, and physiological variables (eg, weight, blood pressure, and blood glucose) for CVD self-management and risk factor control.[21] Combining mHealth technologies and standard preventive measures provides a unique opportunity to enhance secondary CVD prevention in this high-risk group. This American Heart Association scientific statement describes studies that have used mHealth technology for secondary CVD prevention in older adults and reviews the benefits and challenges of mHealth applications in this population.

REVIEW OF THE SCIENTIFIC LITERATURE ON THE USE OF mHEALTH TO IMPROVE CVD OUTCOMES IN OLDER ADULTS

Methods

Systematic computerized literature searches were performed with PubMed, Embase, and Web of Science. The search terms were divided into 3 groups and included terms related to technology, clinical topic, and age limiters. Search terms used within the technology, clinical topic (eg, heart failure), or age groups were divided with "or," and the search terms between the technology, clinical topic, and age groups were connected with "and." The search included technology terms such as *smartphone*, *text message*, *mobile application*, *mHealth*, *iPad*, *wearable sensor*, and *wearable device*, used in conjunction with clinical terms such as *cardiac rehabilitation*, *secondary prevention*, *atrial fibrillation*, *cardiovascular disease*, *coronary heart disease*, *heart failure*, *myocardial infarction*, *cerebrovascular event*, *valvular heart disease*, and *peripheral artery disease*, with the following age-limiting terms: *aged*, *very old*, *older adults*, *elderly*, and *geriatric*. A full list of the search terms used in the search strategy is provided in Supplementary File A.

The search was limited to English language studies of adults with a mean age of ≥60 years published in the past 11 years (2008–August 2019). Bibliographies from related systematic reviews and articles were also reviewed to identify additional applicable studies. Articles focused on CVD screening, detection, and diagnosis (ie, primary CVD prevention), telemedicine (ie, remote

Table 1. mHealth Terminology and Tools

eHealth	No universal consensus on definition; 2 themes: health and technology[1,2]; health services and information delivered or enhanced through the internet and related technologies.[3]
mHealth	No standardized definition has been established[5]; a component of eHealth; medical and public health practice supported by mobile devices (eg, mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices); Global Observatory for eHealth, survey definition; use of mobile and wireless technologies and apps to support the achievement of health objectives[6]; mobile and wearable health information and sensing technologies.[7]
Wearable computers	Computing device worn or carried on the body with user interface ready for use at all times; broadly encompasses tablets, smartphones, and wearable technology.[8]
Wearable technology (wearable tech, wearables)	A category of electronic devices with embedded sensors and analytic algorithms that can track, analyze, and guide wearers' behavior; ability to send and receive data via the internet[9]; smart electronic devices that can be incorporated into clothing or worn on the body as implants or accessories (eg, biometric garments, fitness watches) where they detect, analyze, and transmit information concerning body signals (eg, vital signs) and/or ambient data[9a-9c]; enable data exchange without human intervention (ie, IoT); and can provide immediate biofeedback to the wearer[9d]; different from other portable electronic devices (eg, mobile phones) in that they are designed to be indistinguishable from everyday life so that they may go unnoticed.[10]
IoT	A system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.[11]
Smartwatch	A band unit worn on the wrist comprising an image capture device, a power source, memory, a motion detector, and a display unit; may have the ability to communicate wirelessly with at least 1 portable network device and a server.[12]
Mobile electronic devices (handheld computer)	Any handheld or other portable electronic equipment capable of text messaging, voice communication, entertainment, navigation, accessing the internet, or producing electronic mail, including but not limited to cellular phones, text messaging devices, paging devices, personal digital assistants, and tablet computers.[13]
Mobile integrated therapy	Convergence of mobile technology, clinical and behavioral science, and scientifically validated clinical outcomes.[14]

app indicates application; eHealth, electronic health; IoT, Internet of Things; and mHealth, mobile health.

diagnosis and treatment), and study populations with a mean age of <60 years were excluded. Articles identified from the search were deduplicated, and all abstracts were screened by at least 2 authors. Final selection of relevant articles was based on the information reported in the abstract and screening of the full text to verify applicability and adherence to the inclusion criteria.

Overview of Included Studies

Twenty-six studies examining mHealth for secondary CVD prevention in cohorts with a mean age of ≥60 years were identified by the search strategy. The studies were heterogeneous in terms of the study methodology, mHealth technology examined, and outcomes assessed. Eighteen randomized controlled trials (RCTs) (19 publications),[22–40] 5 pre-post intervention studies,[41–45] 2 feasibility studies,[46,47] and 1 cross-sectional study[48] were identified (Table 2 and Supplementary File B). Eight of the RCTs had a sample size consistent with a priori power calculations (9 publications).[28–31,33,34,36,37,40] Four studies used an SMS-only intervention[23,35–37]; 7 studies had a smartphone application (app)-only intervention[24,27,32,42,44–46]; and 15 studies (16 publications) reported interventions incorporating multiple mHealth modalities (SMS, apps, wearables/devices, websites, or telephone coaching).[22,25,26,28–31,33,34,38–41,43,47,48] Studies included patients with CVD (n=13), heart failure (n=7), hypertension (n=4), atrial fibrillation (n=2), and peripheral artery disease (n=2). On average, studies included subjects with a mean age of 65 years (range, 18–93 years; 3 studies included only subjects >60 years of age),[32,46,48] had moderate sample sizes (median, n=99.5; range, 15–767), and had an intervention period of 3 months (range, 0.5–12 months). Most studies included some evaluation of the feasibility, acceptance, or usability of mHealth (n=18 or outcomes related to secondary prevention of CVD), including medication adherence (n=11), CVD risk factor modification (n=12), or reducing clinical outcomes (eg, all-cause mortality, atrial fibrillation; n=4). Several studies included assessments of quality of life, self-efficacy, knowledge, and self-monitoring behavior (n=14). In the subsequent sections, the findings of the identified trials have been synthesized into 3 broad categories relevant to the use of mHealth technology for secondary prevention of CVD in older adults: Lifestyle Behavior Change, Medication Adherence, and Perceived Ease of Use and Patient Satisfaction. Table 2 includes additional supplemental non–mHealth-related interventions used, including adjunct education and pill boxes.

Lifestyle Behavior Change

Regular exercise, weight management, and a heart-healthy diet are the cornerstone of secondary CVD prevention.[49] The prevalence of physical inactivity is highest among adults ≥65 years of age and, in particular, individuals with CVD, with fewer than one-third being physically active.[50,51] There are unique challenges associated with initiating and maintaining physical activity in older adults with heterogeneity in perceived barriers and motivators based on older age categories and sex.[52] The combination of poor health (eg, health

Table 2. Literature Search Results (Simplified Version of Supplementary File B)

Authors, cardiovascular condition	Sample characteristics, group size, study retention	mHealth technology, intervention, control	Self-monitoring, feedback (if applicable)	Primary outcomes
Ammenwerth et al,[41] CAD	N=25 Women: 4% Mean age: 63 y Duration: 4.5 mo	Mobile app Int: MyCor telemonitoring system. Consists of: smartphone, BP meter, pedometer, and identification card provided on discharge after MI or PCI	Patients measured BP and weight daily, used the pedometer for continuous foot-step counting, documented drug intake and subjective well-being on the smartphone once daily; received tailored goal setting, education, feedback, and regular clinic visits	Percent adherence to daily measurements: Phase 1: 86% Phase 2: 77% Percent adherence to medication: Phase 1: 87% Phase 2: 80% Percent days PA goals reached: Phase 1: 86% Phase 2: 73% ΔHRQOL: +0.08 (P<0.01).
Anthony et al,[22] hypertension	N=121 Women: 42% Mean age: Text: 58.6 y EMR only: 62.2 y EMR+: 61.3 y Duration: 15 d	SMS and EMR Participants randomized to 1 of 3 groups: Int1: record BP in web portal Int2: Int1+text reminder Int3: Int2+2-way text	Participants asked to self-report 14 BP measurements via EMR web portal or text	Bidirectional text group recorded more BP measurements than: EMR-only group (P<0.001) EMR+reminders group (P=0.038) EMR+reminders group recorded more BP measurements than EMR-only group (P<0.001)
Bengtsson et al,[42] hypertension	N=50 Women: 48% Mean age: 59.5 y Duration: 8 wk	Mobile app Int: Interactive Self-Management Support System app for self-management of hypertension 3 Homogeneous subsets of patients used the app	Participants were instructed how to use the system, set up reminders, and monitor BP; self-reported well-being, symptoms, lifestyle, medication intake, side effects, daily home BP and pulse measurements with an automated validated BP monitor; received weekly motivational messages and graphical feedback	ΔBP: SBP: −7 (SD, 18) mm Hg (95% CI, 1.94–12.25; t[48]=2.77 [P=0.008]) DBP: −4.9 (SD, 10) mm Hg (95% CI, 1.95–7.8; t[48]=3.35 [P=0.002])
Cajita et al,[48] HF	N=129 Women: 26.4% Mean age (SD): 71.3 (4.6) y Duration: 45-min survey	mHealth and smartphones In-person and online groups completed survey measuring social influence, ease of use, usefulness, financial cost, intention to use mHealth, eHealth literacy, and smartphone use	Participants answered online survey of social influence, ease of use, usefulness, and financial cost, intention to use mHealth, eHealth literacy, and smartphone use	Influence on intention to use mHealth: Social influence, β=0.17 (P=0.010) Ease of use, β=0.16 (P<0.001) Usefulness, β=0.33 (P<0.001)
Chen et al,[43] CAD	N=190 Women: 31.6% Mean age (SD): 67 (10) y Duration: 3 mo	SMS and mobile app Int: TAKEmeds app Physicians used cell phone app to send automated medication reminders and science-based lifestyle recommendations to their patients. Patients received automatic SMS and calls 4–5 times/wk	Patients received 1-way SMS educational messages. Nonsmokers received messages on each of the following on 4 random weekdays: medication adherence, nutrition, exercise, and general heart health. Smokers received 1 additional message on smoking cessation.	ΔPercentage with high medication adherence: 8.0% ΔPercentage with low medication adherence: −8.0% (OR, 1.80 [95% CI, 1.14–2.85]) ΔSmokers percentage: −5% (P=0.05) ΔDaily consumption of fruit and vegetables: 0.3/d (P=0.01) ΔFacility visits frequency: 3.0 in 3 mo (P=0.04)
Chen et al,[23] CHF	N=767 Women: 43.5% Mean age (SD): 61 (15) y Duration: 6 mo	SMS and STS Int1: Educational and reminder SMS messages Int2: STS Control: Usual care	Participants self-reported measurements (self-care behavior, including medication adherence, weight, salt restriction, water restriction, exercise; HRQOL); patients in SMS group received educational and reminder messages; patients in STS group received 1 structured call from research nurse within 30 d of discharge	180-d composite event rate: SMS (41.3%) and STS (36.5%) lower than control (50.4%) (P<0.05) No difference between SMS and STS (P=0.268) Percent adherence to medication: SMS 78.9% vs STS 81.4% vs control 69.5% (P=0.011) Water restriction: SMS 70.8% vs STS 74.5% vs control 61.5% (P=0.013) HRQOL: Similar among all groups (P=0.526)

(*Continued*)

Table 2. Continued

Authors, cardiovascular condition	Sample characteristics, group size, study retention	mHealth technology, intervention, control	Self-monitoring, feedback (if applicable)	Primary outcomes
Desteghe et al,[45] AF	N=15 Women: 33.3% Mean age (SD): 69.2 (3.7) y Duration: 3 mo	Mobile app Int: Health Buddies app Patients completed daily challenge of taking NOAC medications Patients' grandchildren (their health buddies) completed healthy challenges such as brushing teeth and played educational games	Patients received NOAC refill reminders, daily health challenges, and educational quizzes; self-reported NOAC adherence	Percent NOAC adherence: Taking adherence: 88.6% (SD, 15.4%) Regimen adherence: 81.8% (SD, 18.7%) ΔKnowledge level: +5.8% after 3 mo, (*P*=0.09) Positive app ratings: clarity (1.500), novelty (0.942), stimulation (0.923), and attractiveness (0.859)
Duscha et al,[25] PAD	N=20 Women: 15.8% Mean age (SD): 69.4 (8.4) y Duration: 3 mo	Smartphone and PA tracker Int: Fitbit synced to smartphone, exercise prescription, PAD e-book, coaching Control: Usual care under physician's guidance; no contact with study team; Fitbit worn only for baseline visit, weeks 11 and 12	Intervention group received exercise prescription with Fitbit, educational book on PAD with tip of the week, coaching, and feedback; participants self-monitored daily step count	Mean Δ scores: Peak VO_2: App: 20.3±26.4% (*P*≤0.05) Control: 1.0±6.9% $mL \cdot kg^{-1} \cdot min^{-1}$ (*P*=NS) Claudication onset time: App: 204.6±280.6 s (*P*≤0.05) Control: −21.0±142.7 s (*P*=NS) PA: no significant differences
Duscha et al,[39] CVD	N=25 Women: 24% Mean age (SD): mHealth: 59.9 (8.1) y Control: 66.5 (7.2) y Duration: 3 mo	PA tracker and mobile app Int: Fitbit synced to smartphone, exercise prescription, health coaching through Vida app Control: Usual care under physician's guidance; no contact with study team; Fitbit worn only for baseline visit, weeks 11 and 12	Intervention group self-monitored step count via Fitbit, self-reported physical activity and medication adherence, received coaching and feedback	Mean Δ scores: Absolute peak VO_2: mHealth: 4.7±13.8%, Control: −8.5±11.5% (*P*≤0.05) Moderate-high PA: mHealth: 21±103 min/wk, Control: 46±36 min/wk; (*P*<0.05)
Eyles et al,[24] CVD	N=66 Women: 17% Mean age (SD): 64 (7) y Duration: 6 wk	Mobile app (SaltSwitch) Int: Used SaltSwitch app to identify salt content in groceries Control: Shopped as normal and were able to access usual care CR services for people with CVD	Intervention group downloaded app that provided immediate feedback on salt content in grocery items and low-sodium alternatives	ΔMean household purchases of salt: −0.30 g/MJ (95% CI, −0.58 to −0.03) ΔDaily salt consumption: −0.7 g
Goldstein et al,[26] HF	N=58 Women: 35% Mean age (SD): 69.3 (10.9) y Duration: 4 wk	Electronic pillbox, SMS, and mobile app Participants randomized to 1 of 4 groups: Int1: Smartphone with iRx Reminder app, either silent or with SMS reminder linked to app Int2: Pillbox, either silent or with reminder	Participants in both smartphone groups logged medication taken, able to view list of medications with instructions	Percent adherence: Overall: 78% (SD, 35%) Telehealth device: 80% Smartphone: 76% Reminders: 79% Passive medication reminder devices: 78%
Guo et al,[27] AF	N=209 Women: 44% Mean age (SD): App: 67.4 (10.6) y Control: Duration: 3 mo	Mobile app Int: mAF mobile app with educational materials Control: usual care with 1- and 3-mo follow-up visits	Intervention group self-reported medication adherence, BP, HR, and HRQOL; received education and follow-up reminders; able to upload and view health records and receive feedback from doctors	App vs control: Knowledge: increased Self-care: increased HRQOL: increased Adherence: increased Anticoagulant satisfaction: increased Depression/anxiety: decreased (all *P*<0.05)

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Table 2. Continued

Authors, cardiovascular condition	Sample characteristics, group size, study retention	mHealth technology, intervention, control	Self-monitoring, feedback (if applicable)	Primary outcomes
Hägglund et al,[28] HF	N=82 Women: 32% Mean age (SD): 75 (8) y Duration: 3 mo	Mobile app with tablet Int1: Home intervention system consisted of tablet with mobile app connected to wireless scale Control: Usual care	Intervention group used home intervention system to monitor weight and symptoms, titrate diuretics, and receive information about HF and lifestyle advice according to current guidelines	Improvements at 3 mo: Self-care: Tablet median: 17 (IQR, 13–22) vs control: 21 (IQR, 17–25); $P<0.05$ HRQOL: Tablet median: 65.1 (IQR, 38.5–83.3) vs control: 52.1 (IQR, 41.1–64.1); $P<0.05$ Physical limitations: Tablet median: 54.2 (IQR, 37.7–83.3) vs control: 45.8 (IQR, 25.0–54.2); $P<0.05$ Hospital days for HF: Tablet: 1.3 d/patient Control: 3.5 d/patient (risk ratio, 0.38 [95% CI, 0.31–0.46]; $P<0.05$)
Karhula et al,[29] IHD, HF	N=269 Women: 34% Mean age (SD): 69.6 (9.1) y Duration: 12 mo	Mobile app Int: Telephone coaching, mobile phone with a mobile personal health record app and a set of measurement devices connected to personal health record account Control: Usual care, including disease management information booklet, laboratory tests, 1 appointment with doctor or nurse	Intervention group received remote monitoring system connected to personal health record to self-report measurements (BP, blood glucose, weight, physical activity); received health coaching calls with education and feedback	HRQOL: Physical: β=0.730 (P=0.36) Mental health: β=−0.608 (P=0.62)
Lee et al,[44] AF, HF	N=18 Women: 22% Mean age (SD): 67.28 (8.72) y Duration: 3 mo	Mobile app with tablet Int: Android tablet with MASS mobile app for warfarin therapy	Participants received app with educational modules; encouraged to log bleeding or bruising, set up daily medication reminders, and search vitamin K content of foods	Anticoagulation knowledge: Baseline: 12.5±5.51 Follow-up:14.78±3.93 (P=0.007)
Maddison et al,[30] CAD	N=171 Women: 19% Mean age (SD): 60.2 (9.3) y Duration: 6 mo	SMS and website Int: HEART program with SMS messages, website, and videos aimed at increasing exercise behavior Control: Usual care; both groups had access to CR education and support	Intervention group received exercise prescription, text messages and website with behavior change techniques to enhance self-efficacy; participants self-reported step count, minutes of physical activity	Adjusted mean peak VO_2 at 24 wk: SMS: 27.8 $mL\cdot kg^{-1}\cdot min^{-1}$ Control: 27.9 $mL\cdot kg^{-1}\cdot min^{-1}$ (difference, −0.21 $mL\cdot kg^{-1}\cdot min^{-1}$ [95% CI, 1.1–0.7]; P=0.65)
McDermott et al,[31] PAD	N=200 Women: 52.5% Mean age (SD): 70.2 (10.4) y Duration: 9 mo	PA tracker (Fitbit) and tablet Int: Fitbit, home computer or tablet, telephone coaching Control: Usual care; both groups reported exercise to study team	Intervention group received wearable activity tracker, tablet, phone coaching, and education; participants self-reported walking impairment, physical functioning, mobility, pain interference, satisfaction with social roles and activities, and monitored physical activity	Mean Δ6MW distance: Fitbit 5.5 m vs control 14.4 m (difference, −8.9 m [95% CI, −26.0 to 8.2]; P=0.31)
Mertens et al,[32] CAD	N=24 Women: 50% Mean age (SD): 73.8 y (7.5) y Duration: 8 mo	Mobile app with iPad Study design with 3 sequences: (1) initial phase without assistive systems, (2) interventional phase (28 d of using the Medication Plan app system), (3) comparative phase (28 d of using a paper diary). Users experienced the interventional and comparative phases alternately: half of the users were randomly assigned to each group and switched after 28 d	Intervention group received reminders and logged data using app; participants self-reported medication adherence and BP	Subjective medication adherence: Mean (SD): Baseline: 50.02 (3.44) Intervention phase: 53.96 (2.01) Comparative phase: 52.60 (2.49) (for all pairs after both interventions, $P<0.001$) Objective medication adherence: Significantly stronger for app vs paper diary system (F=27.404; df=1; $P<0.001$) Adherence to BP documentation: Significantly stronger for app vs paper diary (F=361.349; df=1; P=0.033)

(*Continued*)

Table 2. Continued

Authors, cardiovascular condition	Sample characteristics, group size, study retention	mHealth technology, intervention, control	Self-monitoring, feedback (if applicable)	Primary outcomes
Pfaeffli Dale et al,[33] CAD	N=171 SMS: Women: 19% Mean age (SD): 61.38 (8.98) y Duration: 6 mo	SMS and website Int: HEART program with SMS messages, website, and videos aimed at increasing exercise behavior Control: Usual care; both groups had access to CR education and support	Intervention group received exercise prescription, text messages, and website with behavior change techniques to enhance self-efficacy; participants self-reported step count, minutes of physical activity	Participants reporting: Reading SMS: 70/75, 93% Liking content: 55/75, 73%
Pfaeffli Dale et al,[34] CAD	N=123 Women: 19% Mean age (SD): 59.5 (11.1) y Duration: 6 mo	SMS and website Int: Text4Heart program with SMS messages, website, and videos aimed at increasing exercise behavior Control: Usual care; both groups had access to CR education and support	Intervention group received exercise prescription, text messages, and website with behavior change techniques to enhance self-efficacy; participants self-reported step count, minutes of physical activity	ΔPatients adhering to recommended lifestyle behavior change from baseline: 3 mo: SMS: +26%, control: +10% 6 mo: SMS: +20%, control: +12%
Portz et al,[46] HF	N=30 Women: 60% Mean age (SD): 66 (18) y	Mobile app with iPad Int: HF symptom tracker app Part 1: 18 items (5-point Likert scale) inquired about understanding, ability to use app, and ability to report symptoms through app Part 2: Open-ended questions for specific changes or additions and potential caregivers' use of the app	Participants self-reported symptoms and severity, including weight, fatigue, edema, shortness of breath, cough, stomach bloat, feeling sad or anxious	Positive acceptability feedback: app easy to use, understand, and navigate and liked general design Suggested improvements: add specific symptoms (heart palpitations, BP, exercise, and water intake), navigation features, and enhanced instructions for using the app
Quilici et al,[35] ACS	N=499 Women: 23% Mean age: 64 y Duration: 1 mo	SMS Int: Daily text reminders for aspirin intake Control: Usual care	Intervention group received daily personalized SMS reminders and motivational support; participants self-reported aspirin adherence.	%AA-Ag nonadherence: Control, 11.2% vs SMS, 5.2% (OR, 0.43 [95% CI, 0.22–0.86]; P=0.01; NNT=17) SMS: Self-reported nonadherence: 3.6% AA-Ag nonadherence: 5.2% Control: Self-reported nonadherence:16 (6.4%) AA-Ag nonadherence: 28 (11.2%) SMS significantly improves self-reported aspirin adherence (OR, 0.37 [95% CI, 0.15–0.90]; P=0.02; NNT=23)
Varleta et al,[36] hypertension	N=314 Women: 64% Mean age (SD): 60 (10) y Duration: 6 mo	SMS Int: Daily texts tailored to improve medication adherence Control: Usual care	Intervention group received educational texts regarding healthy diet, salt intake, antihypertensive medication schedule, and the importance of medication intake and adherence; participants self-reported medication adherence, dietary intake, HRQOL	ΔPercentage adherence: SMS: 13.3% (P=0.01) Control: −7.9% (P=0.1) SMS improved ADA (risk ratio, 1.3 [95% CI, 1.0–1.6]; P<0.05)
Wald et al,[37] hypertension	N=303 Women: 46% Median age: SMS: 60 y Control: 61 y Duration: 6 mo	SMS Int: Daily texts aimed at improving medication adherence in patients receiving BP or lipid-lowering treatment Control: Usual care	Intervention group received SMS reminders, were asked to answer questions about medications; self-reported medication adherence; telephone calls were made when medications were not taken	SMS: Patients reminded to take meds: 98/150 (65%) Patients resuming treatment: 20/150 (13%) Patients taking <80% prescribed regimen: 14/150 (9%) Control: Patients taking <80% prescribed regimen: 38/151 (25%) ΔMedication adherence SMS vs control: 16% (difference, 95% CI, 7%, 24% [P<0.001])

(*Continued*)

Table 2. Continued

Authors, cardiovascular condition	Sample characteristics, group size, study retention	mHealth technology, intervention, control	Self-monitoring, feedback (if applicable)	Primary outcomes
Widmer et al,[47] CAD, ACS	N=76 Women: 28% Mean age (SD): CR+PHA: 60.2 (12.1) y CR: 70.4 (9.9) y Post CR+PHA: 66.9 (8.3) y Post CR: 69.4 (10.1) y Duration: 3 mo	Mobile app Int1: CR+PHA app Int2: Post CR+PHA app Control: CR and post-CR groups both received usual care	Intervention groups given access to health status information, tasks and targets, email reminders, and a social reinforcement network	ΔWeight: CR+PHA: −4.0+5.2 kg, P=0.001 Post CR+PHA: −2.5±3.8 kg, P=0.04 ΔSystolic BP: CR+PHA: −10.8±13.5 mm Hg, P=0.0009 Post CR+PHA: −12.6±12.4 mm Hg, P=0.001 ΔRehospitalizations/ED visits: CR+PHA: −37.9%, P=0.01 Post CR+PHA: −28%, P=0.04
Widmer et al,[40] CAD, ACS	N=76 Women: 18% Mean age (SD): CR+PHA: 63.6 (10.9) y Control: 62.5 (10.7) y Duration: 3 mo	Mobile app Int: CR + PHA (personal health assistant) app Control: Usual care, according to standard rehab	Intervention group given access to health status information, tasks and targets, email reminders, and a social reinforcement network	ΔWeight: CR+PHA: −5.1±6.5 kg Control: −0.8±3.8 kg; P=0.02 ΔRehospitalizations/ED visits: CR+PHA: 8.1% Control: 26.6% (risk ratio, 0.30 [95% CI, 0.08–1.10]; P=0.054)
Wolf et al,[38] ACS	N=199 Women: 28% Mean age (SD): 60 (10) y Duration: 6 mo	Web-based eHealth tool and mobile app Int1: PCC + eHealth Int2: PCC + no eHealth Control: Usual care, according to standard rehabilitation Intervention group had choice of web-based eHealth tool, mobile app, or both in conjunction with PCC	Participants self-reported self-efficacy, self-rated symptoms of fatigue, motivation, and activity level; given symptom visualization tool, diary, educational links, and chat function for support	No significant difference in mean self-efficacy levels at 6 mo for PCC group without eHealth and PCC+eHealth Patients using eHealth before/after discharge, n (%): PCC+eHealth: 37 (39) PCC+no eHealth: 57 (61) ΔComposite score (improved), n (%): PCC+eHealth: 11 (30) (vs control: P=0.006) PCC+no eHealth: 10 (18) (vs control: P=0.21) Control: 10 (9.5) Events, n: PCC+eHealth: 6 PCC+no eHealth: 12 Control: 16 Return to work: PCC+eHealth: 30/34 (88%) PCC+no eHealth: 47/53 (89%) Control: 89/98 (91%)

AA-Ag indicates acetaminophen-sodium alginate; ACS, acute coronary syndrome; ADA, antihypertensive drug adherence; AF, atrial fibrillation; app, application; BP, blood pressure; CAD, coronary artery disease; CHF, congestive heart failure; CR, cardiac rehabilitation; CVD, cardiovascular disease; DBP, diastolic blood pressure; ED, emergency department; eHealth, electronic health; EMR, electronic medical record; HEART, Heart Exercise and Remote Technologies; HF, heart failure; HR, heart rate; HRQOL, health-related quality of life; IHD, ischemic heart disease; Int, intervention; IQR, interquartile range; MI, myocardial infarction; mHealth, mobile health; NNT, number needed to treat; NOAC, novel oral anticoagulant; NS, nonsignificant; OR, odds ratio; PA, physical activity; PAD, peripheral artery disease; PCC, person-centered care; PCI, percutaneous coronary intervention; PHA, personal health assistant; SBP, systolic blood pressure; 6MW, 6-minute walk test; SMS, short messaging service; and STS, structured telephone support.

problems, injury, illness, pain) and sensory and cognitive impairments that disproportionately affect older adults presents exercise barriers unique to older adults.[52–56] The physical environment (eg, proximity to and perceived safety of sidewalks, parks, recreation centers, and fitness facilities) and a lack of knowledge and understanding of the relationship between exercise and health (eg, poor awareness of the role of exercise in disease prevention and health promotion) are additional exercise barriers unique to older adults.[52–56] However, targeted mHealth strategies have improved health behaviors in older adults with CVD. In the Text4Heart study, bidirectional SMS plus a website increased health behaviors (eg, smoking cessation, fruit and vegetable intake, alcohol intake, physical activity) at 3 months (adjusted odds ratio, 2.55 [95% CI, 1.12–5.84]) compared with a usual care control group, but the difference was not statistically significant at 6 months (adjusted odds ratio, 1.93 [95% CI, 0.83–4.53]).[34] Medication adherence was greater and low-density lipoprotein cholesterol was lower (−0.25 mmol/L [95% CI, −0.49 to 0.01]) in the intervention group at 6 months (these outcomes were not measured at 3 months). In the HEART study (Heart Exercise and Remote Technologies), 3 to 5 SMSs per week plus a supporting website increased leisure-time physical activity (110 min/wk) and walking (151 min/wk) compared with usual care.[30] Three other RCTs examined physical activity in response to multimodal mHealth interventions, all including wearables (with or without apps, websites, telephone coaching, and self-monitoring).[25,31,39] Two of the 3 trials led to improvements in peak VO_2 maximum and increases in moderate to vigorous physical activity among patients with peripheral artery disease[25] and patients after cardiac rehabilitation.[39] Notably, in these 2 studies, the intervention included self-monitoring and personalized coaching (telephone or through the app) with feedback, intervention components that potentially enhanced the physical function and physical activity outcomes observed.[57]

Medication Adherence

Nonadherence to medical therapy is a significant barrier to CVD risk factor optimization. Using mHealth technology significantly improves medication adherence. Eight RCTs that examined the effect of mHealth interventions on medication adherence were identified (median duration, 4.5 months; median, n=356 days).[23,26,27,32,34–37] Four of these studies examined SMS-only interventions[23,35–37]; 1 coupled SMS with a supporting website[34]; and 3 used an app-based intervention.[26,27,32] All SMS-based interventions increased self-reported medication adherence,[23,34–37] and 2 of the 3 app-based interventions improved medication adherence.[27,32] These consistent findings suggest that SMS or app-based reminders may address noncompliance attributable to forgetfulness or cognitive impairment, prompting patients to remember to take their medication and thereby increasing medication adherence. In addition to increased medication adherence (≈14%), Chen et al[23] reported that standardized educational text messages sent to patients with decompensated congestive heart failure within 10 days of discharge and weekly thereafter reduced hospital readmissions and improved event-free survival up to 180 days after discharge. Varleta et al[36] and Wald et al[37] reported that sending standardized text messages for 6 months increased medication adherence in patients taking antihypertensive or lipid-lowering medication by 30% and 16%, respectively. No changes in blood pressure or lipid levels were detected, although the trials were underpowered for these outcomes. Wald et al customized the SMS timing so that patients received the text message at the time they were supposed to take their medication. The messaging was bidirectional, and failure of the patient to provide an affirmative response or take their medication triggered a follow-up telephone call. Overall, the available evidence suggests that interventions including SMS may increase medication adherence in adults with CVD. This is consistent with the conclusions of 2 previous systematic reviews that different methods of mHealth positively affect medication adherence in adults with CVD[21] and that successful mHealth interventions for adults with CVD include personalized, higher-frequency, bidirectional messaging.[58]

Perceived Ease of Use and Patient Satisfaction

In the 14 intervention studies with outcomes related to patient experience, self-reported usability, satisfaction, and acceptance of the mHealth interventions tested were generally high.[22,24,26–28,32–35,41,43–46] In studies with app-only interventions, the majority of patients reported ease of use (>60%),[24,27,32,44,45] patients found the app helpful,[24,27,44] and self-reported use of the app was high.[24,32] However, many of the apps tested were intended for very specific purposes and patients, and the number of eligible patients was very low,[24,45] limiting the external validity. Three of the 5 app-only intervention trials were pilot studies and included <24 subjects.[32,44,45] In a cross-sectional study of older patients with heart failure, perceived ease of use and usefulness were associated with higher intention to use mHealth.

Interventions with SMS tended to report high user engagement. Two studies with participants averaging 60 years of age, HEART and Text4Heart, showed that mHealth interventions improved engagement in health behaviors and CVD risk factor management compared with usual care.[22,33,34] In the HEART trial, 3 to 5 text messages were delivered per week for 6 months; participants also had access to a supporting website. Ninety-three percent of text messages were read; 73% of participants liked the content; and 76% reported the text messages to be motivating.[33] Only 64% of participants used the supporting website, primarily because of difficulty with access and poor user experiences. Similar results were found in the Text4Heart RCT in which patients with coronary artery disease received 1 text message per day for 6 months and had access to a supporting website.[34] Overall, 85% of patients reported reading all of the text messages; 84% thought the right number of text messages were sent; and 95% of subjects engaged in bidirectional text messaging with a mean of 15 responses over the 6-month study period. In contrast, 75% of subjects logged into the website during the study, and only 43% of subjects felt that the website was a good format for program delivery. Both HEART and Text4Heart showed that an mHealth intervention was more effective than a web-based platform for improving engagement in healthy behaviors and CVD risk factor management.

POTENTIAL BENEFITS OF mHEALTH TECHNOLOGY FOR OLDER ADULTS WITH CVD

mHealth technology provides exceptional opportunities for older adults with CVD to improve cardiovascular health and quality of life and to potentially prevent recurrent CVD events.[21,59–62] The persistent negative perceptions about older adults' acceptance and use of mHealth technologies have been refuted by a growing body of evidence.[20,63,64] Novel sensing and communication technologies hold significant promise for monitoring, prompting, encouraging, and educating older adults with CVD who are more prone to adverse events secondary to comorbid conditions, polypharmacy, and declines in functional status.[7,20,27,31,41,48,65–69] With our rapidly expanding aging population comes the potential for significant increases in health care costs[70]; however, innovative mHealth technologies and devices could provide automated and semiautomated ways to control increased expenditures associated with advancing age by enhancing quality of life and cardiovascular health in people with CVD.[59–61,63,71] Benefits from mHealth technology for older adults with CVD may occur in multiple contexts such as improving physical function and enabling active self-management of healthy behaviors and medication adherence that have been shown to improve CVD outcomes.[21,25–27,30–32,39,41,43,61]

Most studies reviewed in this statement demonstrated benefits of mHealth among older patients already comfortable with smart devices or computers, but not all older adults are early adopters of new technologies, which is a challenge in using mHealth technologies for older individuals who lack technological familiarity and digital confidence.[67,72,73] Automating data capture and reporting and providing tailored education and training can address some of the burdens and frustrations experienced by older adults lacking familiarity and comfort with mHealth technologies. Engaging older adults with convenient and easy-to-use technology has been shown to help this high-risk demographic group make small but meaningful changes that can improve health outcomes and minimize social isolation.[64,74,75] mHealth has the potential to link health care professionals, older adults, and their family members through social media[4,7,63,64,68,76–80] while simultaneously and instantaneously assessing physiological metrics and biomarkers.[4,9,27,31,32,34,44–46,64,65,76,77,81–83] This could offer older adults comprehensive lifestyle enhancements and truly revolutionize CVD care in the digital era. However, it is important to note that these issues will lessen as the population of those more adept with technology ages and as technological integration progresses. Ultimately, as mHealth continues to advance, the goal will be to automate and seamlessly integrate the technology into standard health care to improve cardiovascular health on a global scale.

The evolving HATICE trial (Healthy Ageing Through Internet Counselling in the Elderly) highlights the value of eliciting feedback from older adults to guide the development of technologies and adding a coach to support older adults' adoption of mHealth technologies.[84] To have the greatest benefit for older adults, the design of new mHealth products and devices needs to take into account the special considerations of older adults such as simple interfaces and unobtrusive features. Wearable devices in particular have made significant advances over the past decade that could be of benefit to older adults with CVD.[85] When wearing a device, an individual can automatically be monitored for arrhythmias, falls, and other clinical parameters (eg, heart rate, sleep).[69,86] The wearer can also be provided with connectivity, prompts, visual cues, and other enhancements that have the potential to augment self-efficacy for physical activity and medication adherence, important determinants of health-related behavior change, with little added burden. Integrating mHealth into the everyday living patterns of older adults may delay CVD complications and prevent rehospitalization by facilitating communication with health care professionals enhancing disease-specific knowledge and quality of life, and improving physical activity, medication adherence, and smoking cessation.[21,71] As mHealth continues to evolve, it will be critical to engage older adults in the development, optimization, and application of new technologies and devices.

CHALLENGES OF USING mHEALTH TECHNOLOGY FOR OLDER ADULTS WITH CVD

mHealth technology has the potential to positively influence behavioral changes and clinical outcomes in older adults with CVD,[21,87] yet many barriers may prevent use in this population. Existing theories on technology use and adoption suggest that there are 4 overarching factors specific to the adoption of mHealth technology among older adults: personal characteristics, age-related changes, social influence, and privacy issues.[66,88,89]

First, individually or in combination, age (particularly ≥75 years), sex, and socioeconomic status are independent predictors of mHealth adoption for secondary CVD prevention among older adults.[82,90,91] Lower technology use among older adults is more prevalent among racial and ethnic minority groups, as well as individuals with lower levels of income (<$30 000) and lower educational attainment,[77,89] perpetuating the "digital divide." Knowledge, perceptions, experiences, and perceived usefulness of technology influence older adults' digital connectedness, and mHealth use can be associated with these demographic groups. Although studies report conflicting data on attitudes toward and acceptance of technology,[92] older adults' intentions and technology use are limited by social and cultural factors, cost and affordability considerations, and technology usability, as well as perceived relevance or benefit of technology to one's daily life.[58,93,94]

Second, older adults have age-related changes that include physical, visual, hearing, and cognitive impairments that present unique barriers to learning and using mHealth technologies.[67,89,92] In particular, individuals >70 years of age are less inclined to use a smartphone because poor visual and motor coordination limits their ability to operate mobile devices, consequently limiting the potential benefits of mHealth technology in this subpopulation.[58,66] Beyond physical barriers, age-related cognitive barriers such as declines in spatial working memory, lower information processing speed, and a higher negative reaction to errors[95] can limit mHealth literacy and usability, from the early setup (eg, internet and application access) to subsequent tasks that require navigation and interaction skills.[76,78,96] Fragmented digital platforms and services can further exacerbate frustrations and result in demotivation for use.

A third challenge is that certain aspects of digital connectedness and mobile technology use are driven by social influences (ie, subjective norm) that can hinder instead of support older adults' mHealth acceptance and use. For example, some older adults, observing the pervasive use of technology by family members and friends, fear that technology may supplant face-to-face social interactions.[97] Furthermore, research has demonstrated strong associations between social isolation and quality of life among older adults, and technologies have been shown to increase social isolation.[76,96] Although mHealth tools may provide convenient options for health care delivery to some individuals, many older adults may continue to prefer direct in-person contact with health care professionals.

Fourth, privacy issues are a major concern and barrier of mHealth technology adoption among older adults. Newer technologies have focused on smartphones, wearable sensors, and web-based detection of changes in health, with the goal of promoting convenience and the independence of older adults. Except for video recording, many older adults are generally receptive to in-home monitoring and the reporting of this information to health care professionals or family members.[79] However, older adults are less sensitized to the risks of online communication. Consequently, older adults may not have strategies or skills to protect themselves from potential harm or are underprepared for cybersecurity issues or loss of privacy.[89,98,99] Older adults have expressed concern that their health and other sensitive data might be exposed or described vulnerability to solicitations and even cyberattacks.[80] This mistrust of data privacy can be an especially serious obstacle to mHealth adoption.[89,98,99]

DISCUSSION

Our review of the scientific literature on the use of mHealth to support lifestyle modifications and improve medication adherence in older adults with CVD suggests that more research is needed. The heterogeneity of mHealth interventions tested and outcomes assessed and the paucity of studies that examine older adults exclusively limit our ability to provide recommendations and guidelines for using mHealth as a secondary CVD prevention strategy for older adults. The results for studies with a text messaging component look promising, but none of the studies focused solely on older adults (ie, >60 years), so it is difficult to determine the effect of text messaging specific to older adults with CVD. It is also important to note that mHealth was used in a wide variety of ways and is not necessarily successful in its own right but rather because it is used as an adjunct that is often attributable to behavioral interventions rather than the specific technology being applied.

Using mHealth as a secondary CVD prevention strategy in older adults is a relatively understudied area. The type of mHealth technology that is the most effective for older adults with CVD and the specific intervention components that elicit the desired changes in health behaviors are unknown. For example, is real-time continuous monitoring of activity tracking via wearable devices (eg, smartwatch) sufficient to meet recommended physical activity goals, or is more needed (eg, text message prompts, telephone coaching)? Furthermore, the ideal mHealth intervention period for effective and sustained health behavior change and CVD risk reduction has not been identified yet. All of the research studies identified in our search had a relatively short-term focus (ie, intervention period, 0.5–12 months; average duration, 3 months) and substantial heterogeneity in the mHealth technology used and the level of staff contact included in the intervention, and the majority of the included studies did not study older adults exclusively (range, 18–93 years of age; only 3 studies with an inclusion criterion of >60 years of age).[32,46,48] No study examined the mechanistic underpinnings of their findings; therefore, the impact of mHealth interventions on lifestyle behavior change and medication adherence and the resulting effects on CVD risk factor reduction in older adults are not known. It also remains unclear whether there are differences in mHealth effectiveness by race, ethnicity, sex, or age group. Very few studies in the review provided detailed information on participant race and ethnicity, and none included a separate subgroup analysis. In the examined trials, no major differences in outcomes were observed by age or sex, although the samples sizes were relatively small for subgroup analyses. In addition, few identified studies examined behavioral interventions that included mHealth technologies versus behavioral interventions with no technology. Therefore the effectiveness of mHealth relative to traditional behavioral interventions in older adults is unclear.

Many studies conducted to date have focused on intervention development and assessment of feasibility and user satisfaction with limited information on efficacy. An additional challenge in translating the results from mHealth research studies into the clinical care of older patients with CVD is the variety of technologies used across interventions (eg, brands, commercially available versus research grade). Commercially available wearable devices are increasingly being used in research studies, likely because of their lower cost and simple user interface. The most recent systematic review in older community-dwelling adults found that consumer-grade activity trackers are valid in measuring step count and duration of physical activity compared with research-grade devices and visual reference techniques.[100] However, when deciding on a commercially available device for research purposes, it should be noted that the reliability between consumer-grade activity trackers is highly variable, and some consumer-grade devices overestimate step count and duration of physical activity and in general are less accurate in older adults with slower walking speeds.[100] Although ongoing updates to device software can improve the sensitivity and specificity of these devices, many scoring algorithms and, in some cases, raw data are proprietary and thus unavailable to researchers and individual users for analysis and interpretation. In addition, consumer-grade devices requiring frequent and time-consuming updates could lead to frustrations for research participants and even data loss if updates are not completed in a timely manner. Frequent checks for software updates by the researcher and notifications to participants with detailed instructions and guidance on updates can help to mitigate these issues. Future research should focus on additional validation of consumer-grade activity trackers, interdevice reliability, and the efficacy of these devices in patients with CVD, particularly older adults with unique gait patterns and speeds.

Although our review found that most studies reported that satisfaction with and acceptance of the mHealth interventions tested were generally high, the results do not explain the situation for older adults because only 3 of the studies exclusively examined adults >60 years of age.[32,46,48] It is also not clear what technology barriers may be specific to individuals with multiple comorbidities, particularly movement disorders and conditions associated with sensory and cognitive limitations. Future research is needed to identify strategies to translate the results of functional assessments into necessary adaptations of the technology to improve individual use.

There are many patient-level challenges to the adoption of mHealth technology in older adults with CVD beyond those reported in the studies reviewed (access to technology, education and training on how to use mHealth technologies, reliable internet access, etc). The current conceptualization of mHealth demands that patients use a technological platform that remains separate from the therapy that is needed. In other words, older adults must navigate the technology as a prerequisite to the care. This not only is an intimidating requirement for many older adults but often becomes overwhelming and frustrating, particularly when patients are not involved in the development of mHealth interventions, they do not receive sufficient practical training to use the technology, and they do not have family support when technical issues arise (eg, glitches in software updates, connectivity failures). Issues with internet accessibility are also common for patients in remote areas or those without home access. Overcoming these challenges may depend on the future of health care technology that seamlessly integrates mHealth into the gold standard.

The Internet of Things (IoT) can help address many mHealth challenges at the patient level by automating the collection and transfer of health data without human intervention.[11,69] In the 2014 Pew Future of the Internet survey, the vast majority of experts canvassed agreed that the growth of the IoT and embedded and wearable devices will bring the next revolution in digital technology, having widespread and beneficial effects on the everyday lives of the public by 2025.[11,69] In a follow-up survey in 2018, nearly two-thirds of experts agreed that the rise in artificial intelligence and related technology systems would make most people better off over the next decade and that there are many possible applications of artificial intelligence in diagnosing and treating patients or helping senior citizens live fuller and healthier lives.[101] However, experts acknowledged concerns about an individual's autonomy and privacy, stressing the importance of paying close attention when developing, distributing, and updating networks and platforms to make the best use of advanced technologies for human health.[101] The Figure illustrates the conceptualization of a potential IoT application that could reduce the current patient and clinician mHealth challenges related to capturing, reporting, and meaningfully interpreting massive amounts of data created by mHealth technologies. The IoT mHealth application depicted also creates the possibility of automated personalized notifications in real time that could support the behavioral changes needed to improve CVD risk factor management (eg,

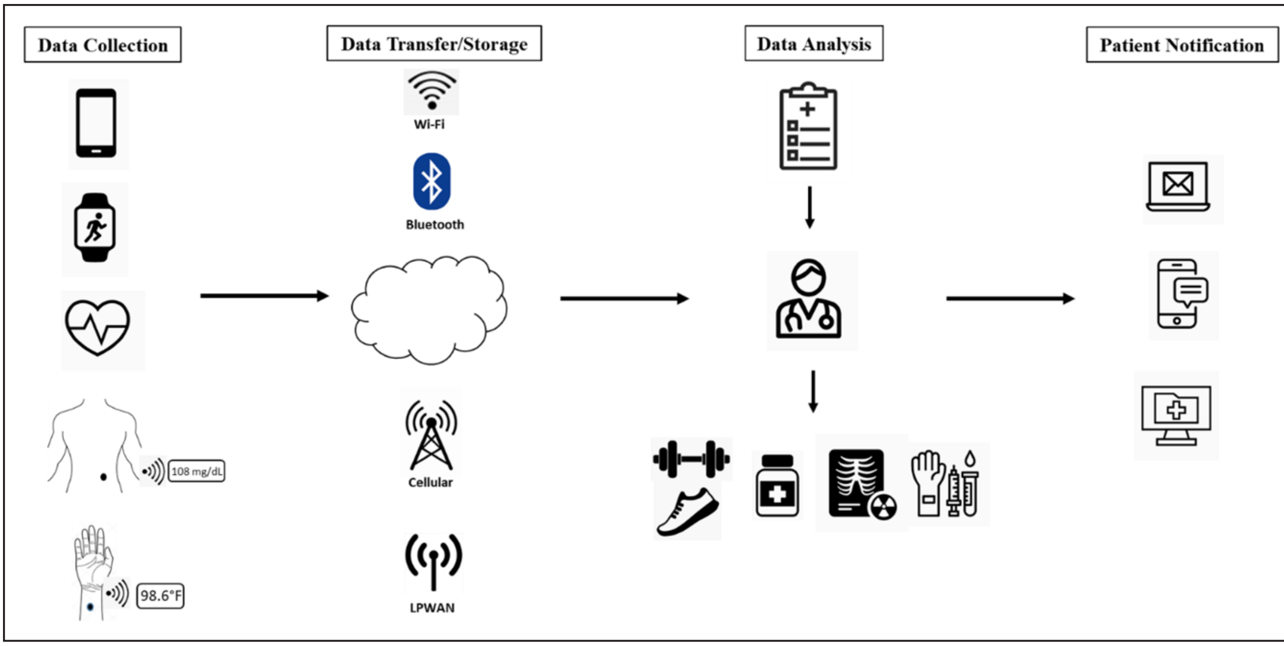

Figure. Internet of Things mobile health application could include automatic capture, transfer, storage, and analysis of health data.
With the use of a combination of advanced data analytics and a clinician's knowledge, personalized recommendations to better manage cardiovascular disease risk factors could be conveyed to the patient via email, mobile phone, or electronic health record. LPWAN indicates low-power wide-area network.

text message to take pro re nata dosage of blood pressure medication to manage hypertension based on the current blood pressure sensor reading).

Similar barriers to mHealth technology adoption exist at the patient-clinician, clinician, and system levels. Factors affecting adoption at the patient-clinician level that require partnership are perceived usefulness and ease of use, design and technical concerns, cost, time, familiarity with the technology, risk-benefit assessment, and communication between health workers and patients.[5,102,103] If these patient-clinician adoption factors are not present, there is a risk that the older adult and the clinician will discontinue use of mHealth, resulting in a gap in care. A potential barrier at the clinician level is the lack of rigorous, published, validated data for consumer mHealth devices in community-dwelling older adults, making it extremely difficult for clinicians to interpret data in an evidence-based way. Although the availability and use of consumer wearable devices continue to increase, health care professionals cannot integrate mHealth data from these devices if they are not clear on how much to trust that information or how to meaningfully interpret the substantial amount of data created from mHealth technologies. Barriers to mHealth technology adoption at the system level include the potential that an older person could have their health protected information compromised, which could also undermine patient-clinician relationships. Research to understand these factors and best practices for training is needed to optimize mHealth adoption at each of these levels.

The key to successful implementation and use of mHealth technology will be individual-, clinician-, and system-level acceptance, communication, and coordination. Additional time and resources will be required to familiarize individuals with the technology and seamlessly integrate it into the delivery of care to older adults with CVD (eg, electronic health record, mHealth links with pharmacies, clinicians, and older adults to improve medication adherence and safety). However, the advancement in electronic health record systems to automatically collect, transfer, and process data from mHealth devices and sensors could address many of the barriers identified (ie, IoT mHealth application). Monitoring, retrieving, and organizing mHealth data are only the initial steps in improving secondary CVD prevention. Using data to improve health care delivery and prompt the initiation and maintenance of behavior changes to reduce CVD risk will be the key to secondary CVD prevention. Achieving this will require ongoing communication and collaboration between multiple disciplines and the use of advanced data analysis methods (eg, big data analytics, machine learning, and artificial intelligence) to create and deliver personalized and meaningful notifications to clinicians and patients related to lifestyle behavior changes, medication adherence, and other clinically relevant interventions. In this way, health care can shift from a reactive model to a proactive model, placing increased importance on disease prevention in addition to treatment.

Limitations

It is possible that the conclusions drawn from our literature review are affected by publication bias, which would result in an overestimation of the effectiveness of mHealth in older adults with CVD. In studies with app-only interventions, the majority of patients reported ease of use (>60%),[24,27,32,44,45] patients found the app helpful,[24,27,44] and self-reported use of the app was high.[24,32] However, many of the apps tested were intended for very specific purposes and patients, and the number of eligible patients was very low,[24,45] limiting the external validity. Three of the 5 app-only intervention trials were pilot studies and included <24 subjects.[32,44,45]

CONCLUSIONS

The literature on mHealth technology for secondary CVD prevention in older adults is limited. Opportunities exist to advance the science of mHealth to contribute to improving CVD outcomes. Current recommendations are that, when an mHealth intervention is implemented for older adults with CVD, a thoughtful approach to secondary prevention should consider personal characteristics, age-related changes, social influence, and privacy issues specific to each patient. As the population of older adults in the United States continues to expand, it is critical to identify and implement effective, widely accepted, cost-effective, and time-efficient mHealth interventions to improve health outcomes for older adults with CVD.

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*Modest.

†Significant.

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*Modest.

†Significant.

REFERENCES

1. World Health Organization eHealth resolution. 58th World Health Assembly. World Health Organization; 2005;28:25.
2. Oh H, Rizo C, Enkin M, Jadad A. What is eHealth (3): a systematic review of published definitions. *J Med Internet Res.* 2005;7:e1. doi: 10.2196/jmir.7.1.e1
3. Eysenbach G, Jadad AR. Evidence-based patient choice and consumer health informatics in the internet age. *J Med Internet Res.* 2001;3:E19. doi: 10.2196/jmir.3.2.e19
4. Kim BY, Lee J. Smart devices for older adults managing chronic disease: a scoping review. *JMIR Mhealth Uhealth.* 2017;5:e69. doi: 10.2196/mhealth.7141
5. Kay M, Santos J, Takane M. *mHealth: New Horizons for Health Through Mobile Technologies*. Geneva, Switzerland: World Health Organization; 2011. Global Observatory for eHealth series, Volume 3. 64:66–71.
6. World Health Organization. mHealth: new horizons for health through mobile technologies: second global survey on eHealth. 2011. Accessed February 17, 2021. https://apps.who.int/iris/handle/10665/44607
7. Kumar S, Nilsen WJ, Abernethy A, Atienza A, Patrick K, Pavel M, Riley WT, Shar A, Spring B, Spruijt-Metz D, et al. Mobile health technology evaluation: the mHealth Evidence Workshop. *Am J Prev Med.* 2013;45:228–236. doi: 10.1016/j.amepre.2013.03.017
8. McCann J, Bryson D. *Smart Clothes and Wearable Technology*. Elsevier; 2009.
9. Schüll ND. Data for life: wearable technology and the design of self-care. *BioSocieties*. 2016;11:317–333.

9a. Düking P, Achtzehn S, Holmberg HC, Sperlich B. Integrated framework of load monitoring by a combination of smartphone applications, wearables and point-of-care testing provides feedback that allows individual responsive adjustments to activities of daily living. *Sensors (Basel)*. 2018;18(5). doi: 10.3390/s18051632

9b. Düking P, Hotho A, Holmberg HC, Fuss FK, Sperlich B. Comparison of non-invasive individual monitoring of the training and health of athletes with commercially available wearable technologies. *Frontiers Physiol*. 2016;7:71. doi: 10.3389/fphys.2016.00071

9c. O'Donoghue J, Herbert J. Data management within mHealth environments: patient sensors, mobile devices, and databases. *J Data Information Qual*. 2012;4:5:1–5:20. doi: 10.1145/2378016.237802 S2CID 2318649

9d. Wearable technology. Wikipedia, Wikimedia Foundation. Accessed March 2, 2021. https://en.wikipedia.org/wiki/Wearable_technology
10. Casson AJ, Yates DC, Smith SJ, Duncan JS, Rodriguez-Villegas E. Wearable electroencephalography. *IEEE Eng Med Biol Magazine*. 2010;29:44–56.
11. Rouse M. Internet of things (IoT). *IOT Agenda*. 2019. Accessed August 14, 2019. https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT
12. Al-Nasser K. Smart watch. US patent application 14/242,627. Filed January 15, 2015.
13. Definition of mobile device. Accessed February 17, 2021. https://www.lawinsider.com/dictionary/mobile-device
14. Peeples MM, Iyer AK, Cohen JL. Integration of a mobile-integrated therapy with electronic health records: lessons learned. *J Diabetes Sci Technol*. 2013;7:602–611. doi: 10.1177/193229681300700304
15. Telemedicine. *Oxford Dictionary.* Accessed February 18, 2021. https://www.lexico.com/en/definition/telemedicine
16. Burke LE, Ma J, Azar KM, Bennett GG, Peterson ED, Zheng Y, Riley W, Stephens J, Shah SH, Suffoletto B, et al; on behalf of the American Heart Association Publications Committee of the Council on Epidemiology and Prevention, Behavior Change Committee of the Council on Cardiometabolic Health, Council on Cardiovascular and Stroke Nursing, Council on Functional Genomics and Translational Biology, Council on Quality of Care and Outcomes Research, and Stroke Council. Current science on consumer use of mobile health for cardiovascular disease prevention: a scientific statement from the American Heart Association [published correction appears in *Circulation*. 2015;132:e233]. *Circulation.* 2015;132:1157–1213. doi: 10.1161/CIR.0000000000000232
17. Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Cheng S, Delling FN, et al; on behalf of the American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2021 update: a report from the American Heart Association. *Circulation*. 2021;143:e254–e743. doi: 10.1161/CIR.0000000000000950
18. Pekkanen J, Linn S, Heiss G, Suchindran CM, Leon A, Rifkind BM, Tyroler HA. Ten-year mortality from cardiovascular disease in relation to cholesterol level among men with and without preexisting cardiovascular disease. *N Engl J Med.* 1990;322:1700–1707. doi: 10.1056/NEJM199006143222403
19. United Nations, Department of Economic and Social Affairs, Population Division. World population ageing 2017—highlights (ST/ESA/SER.A/397). 2017. Accessed February 17, 2021. https://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2017_Highlights.pdf
20. Pew Research Center. Tech adoption climbs among older adults. May 2017. Accessed February 17, 2021. https://www.pewresearch.org/internet/2017/05/17/tech-adoption-climbs-among-older-adults/
21. Coorey GM, Neubeck L, Mulley J, Redfern J. Effectiveness, acceptability and usefulness of mobile applications for cardiovascular disease self-management: systematic review with meta-synthesis of quantitative and qualitative data. *Eur J Prev Cardiol.* 2018;25:505–521. doi: 10.1177/2047487317750913
22. Anthony CA, Polgreen LA, Chounramany J, Foster ED, Goerdt CJ, Miller ML, Suneja M, Segre AM, Carter BL, Polgreen PM. Outpatient blood pressure monitoring using bi-directional text messaging. *J Am Soc Hypertens.* 2015;9:375–381. doi: 10.1016/j.jash.2015.01.008
23. Chen C, Li X, Sun L, Cao S, Kang Y, Hong L, Liang Y, You G, Zhang Q. Post-discharge short message service improves short-term clinical outcome and self-care behaviour in chronic heart failure. *ESC Heart Fail.* 2019;6:164–173. doi: 10.1002/ehf2.12380
24. Eyles H, McLean R, Neal B, Jiang Y, Doughty RN, McLean R, Ni Mhurchu C. A salt-reduction smartphone app supports lower-salt food purchases for people with cardiovascular disease: findings from the SaltSwitch randomised controlled trial. *Eur J Prev Cardiol.* 2017;24:1435–1444. doi: 10.1177/2047487317715713
25. Duscha BD, Piner LW, Patel MP, Crawford LE, Jones WS, Patel MR, Kraus WE. Effects of a 12-week mHealth program on functional capacity and physical activity in patients with peripheral artery disease. *Am J Cardiol.* 2018;122:879–884. doi: 10.1016/j.amjcard.2018.05.018
26. Goldstein CM, Gathright EC, Dolansky MA, Gunstad J, Sterns A, Redle JD, Josephson R, Hughes JW. Randomized controlled feasibility trial of two telemedicine medication reminder systems for older adults with heart failure. *J Telemed Telecare.* 2014;20:293–299. doi: 10.1177/1357633X14541039
27. Guo Y, Chen Y, Lane DA, Liu L, Wang Y, Lip GYH. Mobile health technology for atrial fibrillation management integrating decision support, education, and patient involvement: mAF App Trial. *Am J Med.* 2017;130:1388–1396.e6. doi: 10.1016/j.amjmed.2017.07.003
28. Hägglund E, Lyngå P, Frie F, Ullman B, Persson H, Melin M, Hagerman I. Patient-centred home-based management of heart failure: findings from a randomised clinical trial evaluating a tablet computer for self-care, quality of life and effects on knowledge. *Scand Cardiovasc J.* 2015;49:193–199. doi: 10.3109/14017431.2015.1035319
29. Karhula T, Vuorinen AL, Rääpysjärvi K, Pakanen M, Itkonen P, Tepponen M, Junno UM, Jokinen T, van Gils M, Lähteenmäki J, et al. Telemonitoring and mobile phone-based health coaching among Finnish diabetic and heart disease patients: randomized controlled trial. *J Med Internet Res.* 2015;17:e153. doi: 10.2196/jmir.4059
30. Maddison R, Pfaeffli L, Whittaker R, Stewart R, Kerr A, Jiang Y, Kira G, Leung W, Dalleck L, Carter K, et al. A mobile phone intervention increases physical activity in people with cardiovascular disease: results from the HEART randomized controlled trial. *Eur J Prev Cardiol.* 2015;22:701–709. doi: 10.1177/2047487314535076
31. McDermott MM, Spring B, Berger JS, Treat-Jacobson D, Conte MS, Creager MA, Criqui MH, Ferrucci L, Gornik HL, Guralnik JM, et al. Effect of a home-based exercise intervention of wearable technology and telephone coaching on walking performance in peripheral artery disease: the HONOR randomized clinical trial. *JAMA.* 2018;319:1665–1676. doi: 10.1001/jama.2018.3275
32. Mertens A, Brandl C, Miron-Shatz T, Schlick C, Neumann T, Kribben A, Meister S, Diamantidis CJ, Albrecht UV, Horn P, et al. A mobile application improves therapy-adherence rates in elderly patients undergoing rehabilitation: a crossover design study comparing documentation via iPad with paper-based control. *Medicine (Baltimore).* 2016;95:e4446. doi: 10.1097/MD.0000000000004446
33. Pfaeffli Dale L, Whittaker R, Dixon R, Stewart R, Jiang Y, Carter K, Maddison R. Acceptability of a mobile health exercise-based cardiac rehabilitation intervention: a randomized trial. *J Cardiopulm Rehabil Prev.* 2015;35:312–319. doi: 10.1097/HCR.0000000000000125
34. Pfaeffli Dale L, Whittaker R, Jiang Y, Stewart R, Rolleston A, Maddison R. Text message and internet support for coronary heart disease self-management: results from the Text4Heart randomized controlled trial. *J Med Internet Res.* 2015;17:e237. doi: 10.2196/jmir.4944
35. Quilici J, Fugon L, Beguin S, Morange PE, Bonnet JL, Alessi MC, Carrieri P, Cuisset T. Effect of motivational mobile phone short message service on aspirin adherence after coronary stenting for acute coronary syndrome. *Int J Cardiol.* 2013;168:568–569. doi: 10.1016/j.ijcard.2013.01.252
36. Varleta P, Acevedo M, Akel C, Salinas C, Navarrete C, García A, Echegoyen C, Rodriguez D, Gramusset L, Leon S, et al. Mobile phone text messaging improves antihypertensive drug adherence in the community. *J Clin Hypertens (Greenwich).* 2017;19:1276–1284. doi: 10.1111/jch.13098
37. Wald DS, Bestwick JP, Raiman L, Brendell R, Wald NJ. Randomised trial of text messaging on adherence to cardiovascular preventive treatment (INTERACT trial). *PLoS One.* 2014;9:e114268. doi: 10.1371/journal.pone.0114268
38. Wolf A, Fors A, Ulin K, Thorn J, Swedberg K, Ekman I. An eHealth diary and symptom-tracking tool combined with person-centered care for improving self-efficacy after a diagnosis of acute coronary syndrome: a substudy of a randomized controlled trial. *J Med Internet Res.* 2016;18:e40. doi: 10.2196/jmir.4890
39. Duscha BD, Piner LW, Patel MP, Craig KP, Brady M, McGarrah RW 3rd, Chen C, Kraus WE. Effects of a 12-week mHealth program on peak VO_2 and physical activity patterns after completing cardiac rehabilitation: a randomized controlled trial. *Am Heart J.* 2018;199:105–114. doi: 10.1016/j.ahj.2018.02.001
40. Widmer RJ, Allison TG, Lennon R, Lopez-Jimenez F, Lerman LO, Lerman A. Digital health intervention during cardiac rehabilitation: a randomized controlled trial. *Am Heart J.* 2017;188:65–72. doi: 10.1016/j.ahj.2017.02.016
41. Ammenwerth E, Woess S, Baumgartner C, Fetz B, van der Heidt A, Kastner P, Modre-Osprian R, Welte S, Poelzl G. Evaluation of an integrated telemonitoring surveillance system in patients with coronary heart disease. *Methods Inf Med.* 2015;54:388–397. doi: 10.3414/ME15-02-0002
42. Bengtsson U, Kjellgren K, Hallberg I, Lindwall M, Taft C. Improved blood pressure control using an interactive mobile phone support system. *J Clin Hypertens (Greenwich).* 2016;18:101–108. doi: 10.1111/jch.12682
43. Chen S, Gong E, Kazi DS, Gates AB, Bai R, Fu H, Peng W, De La Cruz G, Chen L, Liu X, et al. Using mobile health intervention to improve secondary prevention of coronary heart diseases in China: mixed-methods feasibility study. *JMIR Mhealth Uhealth.* 2018;6:e9. doi: 10.2196/mhealth.7849

44. Lee JA, Evangelista LS, Moore AA, Juth V, Guo Y, Gago-Masague S, Lem CG, Nguyen M, Khatibi P, Baje M, et al. Feasibility study of a mobile health intervention for older adults on oral anticoagulation therapy. *Gerontol Geriatr Med.* 2016;2:2333721416672970. doi: 10.1177/2333721416672970
45. Desteghe L, Kluts K, Vijgen J, Koopman P, Dilling-Boer D, Schurmans J, Dendale P, Heidbuchel H. The Health Buddies app as a novel tool to improve adherence and knowledge in atrial fibrillation patients: a pilot study. *JMIR Mhealth Uhealth.* 2017;5:e98. doi: 10.2196/mhealth.7420
46. Portz JD, Vehovec A, Dolansky MA, Levin JB, Bull S, Boxer R. The development and acceptability of a mobile application for tracking symptoms of heart failure among older adults. *Telemed J E Health.* 2018;24:161–165. doi: 10.1089/tmj.2017.0036
47. Widmer RJ, Allison TG, Lerman LO, Lerman A. Digital health intervention as an adjunct to cardiac rehabilitation reduces cardiovascular risk factors and rehospitalizations. *J Cardiovasc Transl Res.* 2015;8:283–292. doi: 10.1007/s12265-015-9629-1
48. Cajita MI, Hodgson NA, Budhathoki C, Han HR. Intention to use mHealth in older adults with heart failure. *J Cardiovasc Nurs.* 2017;32:E1–E7. doi: 10.1097/JCN.0000000000000401
49. Fleg JL, Forman DE, Berra K, Bittner V, Blumenthal JA, Chen MA, Cheng S, Kitzman DW, Maurer MS, Rich MW, et al; on behalf of the American Heart Association Committees on Older Populations and Exercise Cardiac Rehabilitation and Prevention of the Council on Clinical Cardiology, Council on Cardiovascular and Stroke Nursing, Council on Lifestyle and Cardiometabolic He. Secondary prevention of atherosclerotic cardiovascular disease in older adults: a scientific statement from the American Heart Association. *Circulation.* 2013;128:2422–2446. doi: 10.1161/01.cir.0000436752.99896.22
50. Kruger J, Ham SA, Sanker S. Physical inactivity during leisure time among older adults: Behavioral Risk Factor Surveillance System, 2005. *J Aging Phys Act.* 2008;16:280–291. doi: 10.1123/japa.16.3.280
51. Centers for Disease Control and Prevention. CDC Behavioral Risk Factor Surveillance Survey. 2019. Accessed February 17, 2021. http://www.cdc.gov/brfss/
52. Schutzer KA, Graves BS. Barriers and motivations to exercise in older adults. *Prev Med.* 2004;39:1056–1061. doi: 10.1016/j.ypmed.2004.04.003
53. Costello E, Kafchinski M, Vrazel J, Sullivan P. Motivators, barriers, and beliefs regarding physical activity in an older adult population. *J Geriatr Phys Ther.* 2011;34:138–147. doi: 10.1519/JPT.0b013e31820e0e71
54. Cohen-Mansfield J, Marx MS, Guralnik JM. Motivators and barriers to exercise in an older community-dwelling population. *J Aging Phys Act.* 2003;11:242–253.
55. Crombie IK, Irvine L, Williams B, McGinnis AR, Slane PW, Alder EM, McMurdo ME. Why older people do not participate in leisure time physical activity: a survey of activity levels, beliefs and deterrents. *Age Ageing.* 2004;33:287–292. doi: 10.1093/ageing/afh089
56. Mathews AE, Laditka SB, Laditka JN, Wilcox S, Corwin SJ, Liu R, Friedman DB, Hunter R, Tseng W, Logsdon RG. Older adults' perceived physical activity enablers and barriers: a multicultural perspective. *J Aging Phys Act.* 2010;18:119–140. doi: 10.1123/japa.18.2.119
57. 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
58. Park LG, Beatty A, Stafford Z, Whooley MA. Mobile phone interventions for the secondary prevention of cardiovascular disease. *Prog Cardiovasc Dis.* 2016;58:639–650. doi: 10.1016/j.pcad.2016.03.002
59. Chen F, Su W, Becker SH, Payne M, Castro Sweet CM, Peters AL, Dall TM. Clinical and economic impact of a digital, remotely-delivered intensive behavioral counseling program on Medicare beneficiaries at risk for diabetes and cardiovascular disease. *PLoS One.* 2016;11:e0163627. doi: 10.1371/journal.pone.0163627
60. Muntaner-Mas A, Vidal-Conti J, Borràs PA, Ortega FB, Palou P. Effects of a Whatsapp-delivered physical activity intervention to enhance health-related physical fitness components and cardiovascular disease risk factors in older adults. *J Sports Med Phys Fitness.* 2017;57:90–102. doi: 10.23736/S0022-4707.16.05918-1
61. Beishuizen CR, Stephan BC, van Gool WA, Brayne C, Peters RJ, Andrieu S, Kivipelto M, Soininen H, Busschers WB, Moll van Charante EP, et al. Web-based interventions targeting cardiovascular risk factors in middle-aged and older people: a systematic review and meta-analysis. *J Med Internet Res.* 2016;18:e55. doi: 10.2196/jmir.5218
62. Forman DE, LaFond K, Panch T, Allsup K, Manning K, Sattelmair J. Utility and efficacy of a smartphone application to enhance the learning and behavior goals of traditional cardiac rehabilitation: a feasibility study. *J Cardiopulm Rehabil Prev.* 2014;34:327–334. doi: 10.1097/HCR.0000000000000058
63. Koch M, Stolee P, MacNeil M, Elliott J, Morita P, Kuspinar A, Juzwishin D. Innovation processes for ageing-related health technologies. *Healthc Manage Forum.* 2021;34:34–42. doi: 10.1177/0840470420936715
64. Gell NM, Rosenberg DE, Demiris G, LaCroix AZ, Patel KV. Patterns of technology use among older adults with and without disabilities. *Gerontologist.* 2015;55:412–421. doi: 10.1093/geront/gnt166
65. Free C, Phillips G, Watson L, Galli L, Felix L, Edwards P, Patel V, Haines A. The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. *PLoS Med.* 2013;10:e1001363. doi: 10.1371/journal.pmed.1001363
66 Lee C, Coughlin JF. Perspective: older adults' adoption of technology: an integrated approach to identifying determinants and barriers. *J Product Innovation Manage*. 2015;32:747–759.
67. Spann A, Stewart E. Barriers and facilitators of older people's mHealth usage: a qualitative review of older people's views. *Human Technol*. 2018;14:264–296.
68. Blaschke CM, Freddolino PP, Mullen EE. Ageing and technology: a review of the research literature. *Br J Social Work*. 2020;39:641–656.
69. Pew Research Center. The Internet of Things will thrive by 2025. May 2014. Accessed February 21, 2021. https://www.pewresearch.org/internet/2014/05/14/internet-of-things/
70. Martini EM, Garrett N, Lindquist T, Isham GJ. The boomers are coming: a total cost of care model of the impact of population aging on health care costs in the United States by major practice category. *Health Serv Res.* 2007;42(pt 1):201–218. doi: 10.1111/j.1475-6773.2006.00607.x
71. Widmer RJ, Collins NM, Collins CS, West CP, Lerman LO, Lerman A. Digital health interventions for the prevention of cardiovascular disease: a systematic review and meta-analysis. *Mayo Clin Proc.* 2015;90:469–480. doi: 10.1016/j.mayocp.2014.12.026
72. Boise L, Wild K, Mattek N, Ruhl M, Dodge HH, Kaye J. Willingness of older adults to share data and privacy concerns after exposure to unobtrusive in-home monitoring. *Gerontechnology.* 2013;11:428–435. doi: 10.4017/gt.2013.11.3.001.00
73. Wildenbos GA, Jaspers MWM, Schijven MP, Dusseljee-Peute LW. Mobile health for older adult patients: using an aging barriers framework to classify usability problems. *Int J Med Inform.* 2019;124:68–77. doi: 10.1016/j.ijmedinf.2019.01.006
74. McMahon S, Lewis B, Oakes M, Guan W, Wyman J, Rothman A. Older Adults' Experiences Using a Commercially Available Monitor to Self-Track Their Physical Activity. *JMIR mHealth and uHealth*. 2016;4:e35. doi: 10.2196/mhealth.5120
75. Gandapur Y, Kianoush S, Kelli HM, Misra S, Urrea B, Blaha MJ, Graham G, Marvel FA, Martin SS. The role of mHealth for improving medication adherence in patients with cardiovascular disease: a systematic review. *Eur Heart J Qual Care Clin Outcomes.* 2016;2:237–244. doi: 10.1093/ehjqcco/qcw018
76. Aarts S, Peek ST, Wouters EJ. The relation between social network site usage and loneliness and mental health in community-dwelling older adults. *Int J Geriatr Psychiatry.* 2015;30:942–949. doi: 10.1002/gps.4241
77. Levine DM, Lipsitz SR, Linder JA. Trends in seniors' use of digital health technology in the United States, 2011-2014. *JAMA.* 2016;316:538–540. doi: 10.1001/jama.2016.9124
78. Antonucci TC, Ajrouch KJ, Manalel JA. Social relations and technology: continuity, context, and change. *Innov Aging.* 2017;1:igx029. doi: 10.1093/geroni/igx029
79. Epstein I, Aligato A, Krimmel T, Mihailidis A. Older adults' and caregivers' perspectives on in-home monitoring technology. *J Gerontol Nurs.* 2016;42:43–50. doi: 10.3928/00989134-20160308-02
80. Wang S, Bolling K, Mao W, Reichstadt J, Jeste D, Kim HC, Nebeker C. Technology to support aging in place: older adults' perspectives. *Healthcare (Basel).* 2019;7:60. doi: 10.3390/healthcare7020060
81. Cajita MI, Gleason KT, Han HR. A systematic review of mHealth-based heart failure interventions. *J Cardiovasc Nurs.* 2016;31:E10–E22. doi: 10.1097/JCN.0000000000000305
82. Park LG, Ng F, K Shim J, Elnaggar A, Villero O. Perceptions and experiences of using mobile technology for medication adherence among older adults with coronary heart disease: a qualitative study. *Digit Health.* 2020;6:2055207620926844. doi: 10.1177/2055207620926844

83. Vegesna A, Tran M, Angelaccio M, Arcona S. Remote patient monitoring via non-invasive digital technologies: a systematic review. *Telemed J E Health.* 2017;23:3–17. doi: 10.1089/tmj.2016.0051
84. Richard E, Jongstra S, Soininen H, Brayne C, Moll van Charante EP, Meiller Y, van der Groep B, Beishuizen CR, Mangialasche F, Barbera M, et al. Healthy ageing through internet counselling in the elderly: the HATICE randomised controlled trial for the prevention of cardiovascular disease and cognitive impairment. *BMJ Open.* 2016;6:e010806. doi: 10.1136/bmjopen-2015-010806
85. Bonato P. Advances in wearable technology for rehabilitation. *Stud Health Technol Inform.* 2009;145:145–159.
86. Mercer K, Giangregorio L, Schneider E, Chilana P, Li M, Grindrod K. Acceptance of commercially available wearable activity trackers among adults aged over 50 and with chronic illness: a mixed-methods evaluation. *JMIR mHealth and uHealth*. 2016;4:e7. doi: 10.2196/mhealth.4225
87. 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
88. Mohammed S, Glennerster R, Khan AJ. Impact of a daily SMS medication reminder system on tuberculosis treatment outcomes: a randomized controlled trial. *PLoS One.* 2016;11:e0162944. doi: 10.1371/journal.pone.0162944
89. Pew Research Center. Older adults and technology use. April 2014. Accessed February 21, 2021. https://www.pewresearch.org/internet/2014/04/03/older-adults-and-technology-use/
90. Jung C, Padman R, Shevchik G, Paone S. Who are portal users vs. early e-Visit adopters? a preliminary analysis. *AMIA Annu Symp Proc.* 2011;2011:1070–1079.
91. Reddy R, Majmudar M, Dhopeshwarkar N, Vacaro V, Isselbacher E, Bhatt AB. Mobile health apps preferences and practice among ambulatory cardiovascular patients. *Future Cardiol.* 2018;14:381–388. doi: 10.2217/fca-2018-0005
92. Lee CC, Czaja SJ, Moxley JH, Sharit J, Boot WR, Charness N, Rogers WA. Attitudes toward computers across adulthood from 1994 to 2013. *Gerontologist.* 2019;59:22–33. doi: 10.1093/geront/gny081
93. Chen K, Chan AH. Gerontechnology acceptance by elderly Hong Kong Chinese: a senior technology acceptance model (STAM). *Ergonomics.* 2014;57:635–652. doi: 10.1080/00140139.2014.895855
94. Fox CS, Hwang SJ, Nieto K, Valentino M, Mutalik K, Massaro JM, Benjamin EJ, Murabito JM. Digital connectedness in the Framingham Heart Study. *J Am Heart Assoc.* 2016;5:e003193. doi: 10.1161/JAHA.116.003193
95. Leung R, Tang C, Haddad S, Mcgrenere J, Graf P, Ingriany V. How older adults learn to use mobile devices: survey and field investigations. *ACM Trans Accessible Computing (TACCESS)*. 2012;4:1–33.
96. Cornwell EY, Waite LJ. Social disconnectedness, perceived isolation, and health among older adults. *J Health Soc Behav.* 2009;50:31–48. doi: 10.1177/002214650905000103
97. Harst L, Lantzsch H, Scheibe M. Theories predicting end-user acceptance of telemedicine use: systematic review. *J Med Internet Res.* 2019;21:e13117. doi: 10.2196/13117
98. Zulman DM, Kirch M, Zheng K, An LC. Trust in the internet as a health resource among older adults: analysis of data from a nationally representative survey. *J Med Internet Res.* 2011;13:e19. doi: 10.2196/jmir.1552
99. Wildenbos GA, Peute L, Jaspers M. Aging barriers influencing mobile health usability for older adults: a literature based framework (MOLD-US). *Int J Med Inform.* 2018;114:66–75. doi: 10.1016/j.ijmedinf.2018.03.012
100. Straiton N, Alharbi M, Bauman A, Neubeck L, Gullick J, Bhindi R, Gallagher R. The validity and reliability of consumer-grade activity trackers in older, community-dwelling adults: a systematic review. *Maturitas.* 2018;112:85–93. doi: 10.1016/j.maturitas.2018.03.016
101. Pew Research Center. Artificial intelligence and the future of humans. December 2018. Accessed February 21, 2021. https://www.pewresearch.org/internet/2018/12/10/artificial-intelligence-and-the-future-of-humans/
102. Gagnon MP, Payne-Gagnon J, Breton E, Fortin JP, Khoury L, Dolovich L, Price D, Wiljer D, Bartlett G, Archer N. Adoption of electronic personal health records in Canada: perceptions of stakeholders. *Int J Health Policy Manag.* 2016;5:425–433. doi: 10.15171/ijhpm.2016.36
103. White A, Thomas DS, Ezeanochie N, Bull S. Health worker mHealth utilization: a systematic review. *Comput Inform Nurs.* 2016;34:206–213. doi: 10.1097/CIN.0000000000000231