A Systematic Review of Digital Health Solutions for Cardiovascular Disease Prevention

Yihan Qi, Emma Mohamad, Arina Anis Azlan, Chenglin Zhang, Yilian Ma, Anqi Wu

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Table of Contents

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Abstract

Background: Cardiovascular disease (CVD) remains a critical global health concern, contributing significantly to global mortality rates, with approximately 70% of cases linked to modifiable risk factors. While traditional methods for CVD prevention face challenges, digital health technologies offer promising avenues for intervention. However, the extent to which these technologies comprehensively address the spectrum of CVD prevention strategies remains unclear. Currently, there is an absence of systematic evaluations within the existing literature regarding the effectiveness and scope of digital solutions in CVD prevention. This emphasizes the need for examination and synthesis of available research to guide future developments and implementations.

Objective: This review aims to make a thorough analysis of how digital technologies can effectively tackle the challenges posed by traditional approaches to CVD prevention. This review aims to consolidate existing literature on digital solutions for CVD prevention, delineate the key components of successful CVD prevention targeted by digital solutions, and outline the research gaps requiring attention to foster the development of sustainable and scalable digital solutions for CVD prevention.

Methods: Our methodology involved identifying primary literature on CVD prevention using digital solutions, specifically technologies facilitating remote care beyond traditional telephone use. Utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework as a guideline, we searched comprehensively in Web of Science, Scopus, and PubMed to retrieve original studies published in English between January 2000 and May 2024.

Results: Our search identified 30 eligible studies, with 24 (80%) being randomized controlled trials (RCTs). The digital solutions reviewed for CVD prevention primarily focused on baseline assessment (97%,), physical activity counseling (60%), tobacco cessation (47%), blood pressure management (43%), and medication adherence (33%). Technologies such as smartphones and
wearables (53%), email and short message service (SMS) communications (40%), and websites or web portals (10%) were utilized in the studies. Approximately half of the studies addressed blood pressure, exercise capacity, and weight, whereas less than a third addressed medication use, quality of life, dietary habits, intervention adherence, waist circumference, and blood glucose
levels.

Conclusions: Digital solution has the potential to alleviate challenges associated with traditional CVD prevention approaches by enhancing preventive behaviors and monitoring health indicators. However, evaluated interventions have predominantly focused on medication use, quality of life, dietary habits, intervention adherence, and waist. Thus, subsequent studies are crucial with more extensive interventions in CVD prevention for assessing their lasting effect on key cardiovascular outcomes. Clinical Trial: -

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Review

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Keywords: cardiovascular disease prevention; cardiovascular outcomes; digital technologies; remote care

Introduction

Cardiovascular Disease Prevention

Cardiovascular disease (CVD) remains a significant worldwide health issue, making a contribution to global mortality. Approximately 70% of CVD cases are due to modifiable risk factors [1], these include lifestyle-related elements such as physical inactivity, poor dietary habits, high levels of blood pressure, and tobacco use. CVD prevention includes primary, secondary, and tertiary stages. Primary prevention targets high-risk individuals without CVD [2], secondary prevention focuses on those with established CVD, and tertiary prevention is for individuals seriously affected by CVD and aims to enhance their life expectancy [3]. Tertiary prevention involves procedures such as coronary angioplasty, stenting, and bypass surgery to prevent disease progression, therefore this study only focused on primary and secondary prevention strategies to prevent the risk of CVD and slow progression. However, despite the evidence supporting the effectiveness of CVD prevention initiatives, there is a significant difference between the potential benefits and the actual participation of individuals. Participation rates in preventive strategies still remain low, and adherence to lifestyle changes and medical recommendations is still unstable [4,5]. This arises from challenges such as socioeconomic inequalities, differences in timing of participation, limited awareness or understanding of preventive strategies, restricted access to healthcare resources, and barriers related to transportation and distance [6]. Furthermore, barriers in healthcare systems, such as insufficient funding, fragmented care delivery, and inadequate integration, further hinder the adoption of CVD prevention measures [3].

Digital Solutions for CVD Prevention

Technological advances in CVD prevention offer solutions to the limitations of traditional facility-based measures. Mobile applications, wearable devices, telemedicine, and remote monitoring systems can improve individual engagement and adherence. These approaches can provide personalized instructions, real-time monitoring, and remote consultations, making it easier to manage their cardiovascular health. Additionally, these digital approaches can reach broader populations, including those with limited access to healthcare facilities. In this study, we employ digital health solutions to incorporate a range of technologies to facilitate care delivery. This way acknowledges the variety of digital tools available, including eHealth, mHealth, short message service (SMS), wearable devices, mobile applications, and telemedicine. Although studies have shown the results regarding the effectiveness of digital health solutions in CVD prevention, such as those delivered through mobile applications, these are largely restricted to specific settings and have not yet been broadly implemented in clinical practice [7,8]. Digital solutions have considerable potential to improve the results of the CVD prevention by improving accessibility, efficiency, and individual engagement. However, to incorporate these innovations into everyday healthcare, various barriers must be addressed, including regulatory issues, interoperability challenges, and limitations within the healthcare system.

At present, there is a lack of understanding about how well digital solutions for CVD prevention cover the elements of CVD prevention and their success in achieving the desired results. Therefore, the focus of this study is to evaluate digital technologies for CVD prevention and to evaluate the thoroughness of these solutions. Given the growing need for technological innovation to reshape the CVD prevention landscape, this study serves multiple purposes: Firstly, it integrates existing literature on digital solutions for CVD prevention. Secondly, it identifies key components of CVD prevention that are effectively addressed through digital solutions. Finally, it charts the gaps that need attention to facilitate the sustainable integration of digital solutions for CVD prevention into clinical practice.

Methods

We use key questions regarding the design of studies to evaluate CVD prevention, including technologies utilized, sample sizes, time of interventions and follow-up periods, key findings, and the comprehensiveness of the investigated solutions. Our approach adheres strictly to established guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [9].

Eligibility Criteria

Our search included Web of Science, Scopus, and PubMed for studies published in English between January 2000 and May 2024 on digital solutions to prevent CVD. For the purposes of this review, ‘digital’ refers to the use of advanced technologies to provide remote behavioral interventions and these digital technologies extend beyond basic telephonic communication. Specifically, it includes Internet-based platforms that facilitate interactive and personalized health interventions, wearable devices that monitor and provide feedback on physiological parameters, and mobile applications that provide user-friendly interfaces for tracking health behaviors, receiving educational content, and participating in virtual tutoring sessions. As noted in the American College of Cardiology Scientific Statement on CVD Prevention [10], studies that relied solely on telephone interventions were not included in this review.

We use a two-step process to assess eligibility for inclusion. Initially, the article titles and abstracts were reviewed for relevance. Following this, a thorough examination of the full text was performed to ensure it met the pre-established criteria. Articles were selected if (1) they conducted an original study using telemedicine or digital methods specifically aimed at CVD prevention, and (2) reported findings regarding feasibility and usability. At the same time, we have clearly defined exclusion criteria to maintain quality. Specifically, articles were excluded if (1) there were only abstracts but no accessible full version, (2) the articles focused only on methodological part without providing primary data, (3) the articles were not designed to involve any participants or groups of people, or (4) the articles lacked a follow-up period, such as a cross-sectional study that does not track results over time.

Systematic Review Process

The review process consisted of several stages, beginning with a search on Web of Science, Scopus and PubMed databases in May 2024. The search string was created by merging keywords related to digital technologies of healthcare, prevention measures, and CVD. The specific search terms we used were detailed in Appendix 1. All retrieved articles then proceed to the next title and abstract filtering stage. To facilitate filtering, articles and abstracts are exported to do the filtering process in Microsoft Excel.

2871 articles were searched from the Web of Science, Scopus, and PubMed. The title and abstract filtering found redundancy, and as a result, 1542 duplicates were removed, resulting in 1329 articles advancing to the next stage of the filtering process. In the initial quality assessment process, we used a peer review method involving all researchers. At this stage, researchers read the title and abstract of each article to determine which articles will advance to the full-text screening stage. During the full-text screening stage, the selected articles were thoroughly reviewed and those articles with researchers' consensus were included. Of the 1329 articles reviewed on the titles and abstracts, 261 were selected for detailed full-text reading based on the consensus of the researchers. 1068 articles were excluded because their titles and abstracts were not related to the use of telemedicine or digital solutions to prevent CVD. In the end, the entire screening process produced 30 eligible articles. Beyond the initial peer review quality assessment process, we used the assessment methodology of Abouzahra et al. [11] to reassess the quality of 30 eligible articles. This involved evaluating each article based on 6 questions and assigning a score, if an article has an overall score of more than 3.0, it is considered to be of sufficient quality and is included in the review. According to our quality assessment, all articles met the good quality standards as shown in Appendix 2. The exclusion of 231 articles was mainly due to secondary analysis, conference abstracts, protocol papers, lack of original research, and lack of follow-up period. For instance, a study by Ernsting et al. was excluded as although it discussed the potential of mobile health applications to change health-related behaviors and manage chronic conditions in patients with CVDs and diabetes mellitus [12], it was a cross-sectional study that did not track outcomes over time and lacked follow-up periods. Figure 1 illustrated the flow of this process.

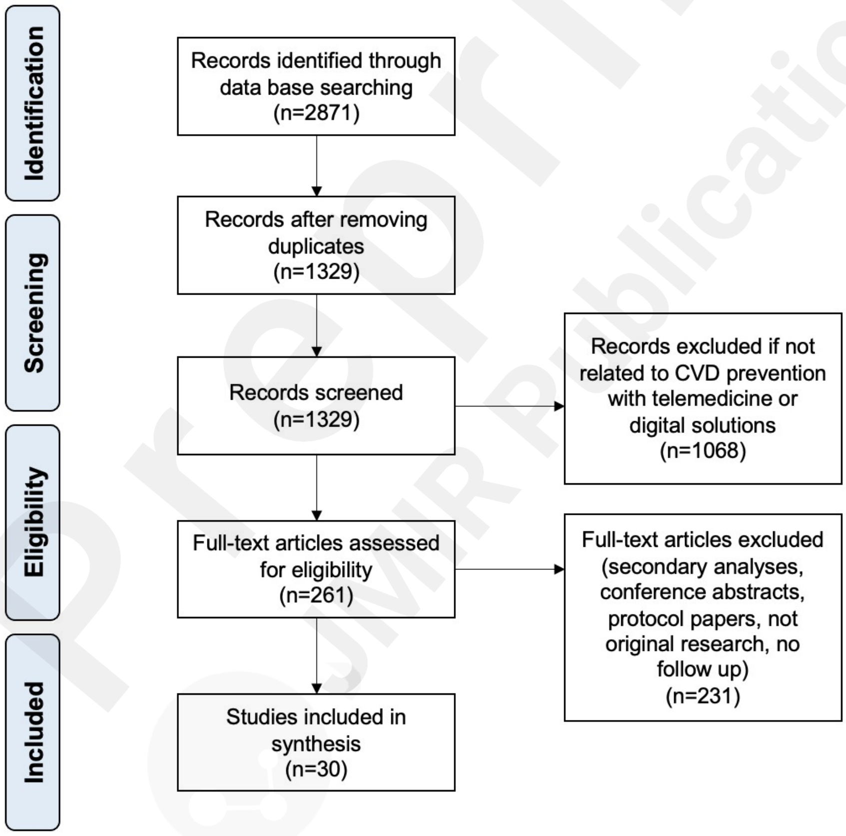


Figure 1. PRISMA flowchart

Data Evaluation

To ensure a detailed assessment of CVD prevention across all 30 articles, we documented the specific measures used in each article. Our approach follows the American Heart Association consensus statement [13] and Guide to Primary Prevention of Cardiovascular Diseases [14] about the components of primary and secondary CVD prevention. In addition, we divided the digital solutions outlined in each article into two groups: those that operate independently and those that enhance traditional approaches to CVD prevention. According to Wongvibulsin et al. [15], articles were classified as standalone solutions if the intervention primarily utilizes remote teaching, with the initial face-to-face meeting dedicated to onboard, baseline assessment, or outcome assessment, provided the primary intervention was conducted remotely. Moreover, we observed other characteristics including CVD prevention type, study countries, study designs applied, participation and population, duration of intervention or follow-up, personnel used, and delivery settings.

Result

Characteristics of the Eligible Studies

This review included 30 studies meeting the inclusion criteria detailed in Table 1, with their characteristics detailed in Table 2. Of the 30 studies, 24 studies (24/30, 80%) were RCTs and 23 studies focused on secondary prevention (23/30, 77%). Most of these studies were conducted in the Americas (19/30, 63%). The median sample size was 465.5 (IQR 162.75-751.5), with a median follow-up period of 6 months (IQR 3.5-12) and a median intervention duration of 6 months (IQR 3-12). 28 (28/30, 93%) were standalone digital CVD prevention interventions. In Figure 2, the most frequently components of CVD prevention were baseline assessment (29/30, 97%), physical activity counseling (18/30, 60%), tobacco cessation (14/30, 47%), blood pressure management (13/30, 43%), and medication adherence (10/30, 33%). Approximately one-third of the studies covered additional components of CVD prevention, such as disease knowledge (9/30, 30%) and exercise training (9/30, 30%). Less than one-third of the studies focused on nutrition counseling (8/30, 27%), lipid (8/30, 27%), psychological management (7/30, 23%), diabetes (6/30, 20%), weight (6/30, 20%), heart rate (5/30, 17%), blood glucose (1/30, 3%), and alcohol use (1/30, 3%). Smartphones and wearables were utilized in 53% (16/30), email-SMS communications in 40% (12/30), and websites or web portals in 10% (3/30). Interventions are most often directed by research team staff (26/30, 87%), followed by health coaches (3/30, 10%), physicians (3/30, 10%), health professionals (3/30, 10%), nurses (2/30, 7%), dietitians (1/30, 3%), pharmacists (1/30, 3%), and community health workers (1/30, 3%). The most frequently evaluated outcome was blood pressure (14/30, 47%). Other commonly assessed outcomes included exercise capacity (12/30, 40%), weight (12/30, 40%), lipid profile (11/30, 37%), nicotine dependence (9/30, 30%), medication use (8/30, 27%), quality of life (7/30, 23%), dietary habits (5/30, 17%), intervention adherence (4/30, 13%), waist (4/30, 13%), and blood glucose (2/30, 7%).

Reference	Prevention Type	Location	Research Design and Participation	Intervention Measures	Components of CVD prevention	Personnel and Delivery Setting	Outcomes	Follow-up and Intervention Duration
Chow et al., 2015 [16]	Secondary	Australia	RCT among 710 patients with documented coronary heart disease (CHD)	6-month intervention of the tobacco, exercise and diet messages (TEXT ME) program	• Baseline assessment • Tobacco cessation • Physical activity counseling • Nutrition counseling • Disease knowledge	• Standalone intervention • Researcher	• Lipid profile • Blood pressure • Weight • Exercise capacity • Nicotine dependence	• 6 months, • 6 months
Maddison et al., 2015 [17]	Secondary	New Zealand	RCT among 171 patients with ischemic heart disease	24-week Heart Exercise And Remote Technologies intervention about personalized, automated package of text messages and secure website with video messages	• Baseline assessment • Exercise training • Psychological management	• Standalone intervention • Researcher, staff	• Oxygen uptake • Exercise capacity • Self-efficacy • Quality of life • Economic evaluation	• 6 months • 6 months
Anand et al., 2016 [18]	Primary	Canada	RCT with 343 people who were free of CVD	12-month emails or text messages program	• Baseline assessment • Physical activity counseling • Nutrition counseling	• Standalone intervention • Researcher	• Myocardial infarction • Blood pressure • Waist	• 12 months • 12 months
Johnston et	Secondary	Sweden	RCT with 174	6-month	• Baseline	• In-person	• Weight	• 6 months

al., 2016 [19]			myocardial infarction patients	interactive patient support application on phone	assessment • Weight management • Exercise training • Tobacco cessation • Blood pressure management • Blood glucose management	session • Standalone intervention • Nurse, physician	• Exercise capacity • Nicotine dependence • Medication use • Intervention adherence • Quality of life • Satisfaction	• 6 months
Redfern et al., 2016 [20]	Secondary	Australia	RCT among 1301 patients with CHD	6-month text messages intervention of TEXT ME program	• Baseline assessment • Tobacco cessation • Physical activity counseling • Nutrition counseling • Disease knowledge	• In-person session • Standalone intervention • Group session • Researcher	• Lipid profile • Blood pressure • Weight • Exercise capacity • Nicotine dependence	• 12 months • 6 months
Thakkar et al., 2016 [21]	Secondary	Australia	RCT among 710 patients with CHD	6-month text messages intervention of TEXT ME program	• Baseline assessment • Tobacco cessation • Physical activity counseling • Nutrition counseling • Disease knowledge	• Standalone intervention • Researcher	• Exercise capacity	• 6 months • 6 months
Akhu-Zaheya & Shiyab, 2017 [22]	Secondary	Jordan	RCT among 160 patients with CVD	3-month SMS intervention	• Baseline assessment • Tobacco cessation • Medication adherence • Nutrition counseling	• Standalone intervention • Researcher	• Medication use • Dietary habits • Nicotine dependence	• 6 months • 3 months
Jones et al., 2018 [23]	Primary	United States	Qualitative study among 40 people at risk for CVD	12-week short message system and longer text messages intervention	• Baseline assessment • Blood pressure management • Weight management • Lipid management • Exercise training • Medication adherence • Nutrition counseling	• In-person session • Group session • Researcher	• Weight • Waist • Lipid profile • Blood pressure	• 3 months • 3 months
Morawski et al., 2018 [24]	Primary	United States	RCT among 411 hypertensive patients	12-week smartphone application intervention	• Baseline assessment • Blood pressure management • Medication adherence	• Standalone intervention • Researcher	• Blood pressure • Medication use	• 3 months • 3 months
Santo et al., 2018 [25]	Secondary	Australia	RCT among 710 patients with CHD	6-month intervention of TEXT ME	• Baseline assessment • Nutrition counseling • Blood pressure management • Lipid management • Weight management • Tobacco cessation • Physical activity counseling	• Standalone intervention • Researcher	• Lipid profile • Weight • Dietary habits	• 6 months • 6 months
Beratarrechea et al., 2019 [26]	Primary	Argentina	RCT among 755 people at risk for CVD	6-month mHealth application intervention for calculating CVD risk	• Baseline assessment • Blood pressure management • Disease knowledge	• Standalone intervention Study administrative staff, healthcare professionals, community health worker	• Medication use • Health outcomes • Nicotine dependence	• 12 months • 6 months
Brasier et al., 2019 [27]	Secondary	Switzerland and Germany	Prospective randomized study among 672 patients with presumed atrial fibrillation	12-month smartphones intervention with installed a study version of the commercially available	• Baseline assessment • Heart rate management	• Standalone intervention • Researcher, cardiology physician	• Detection of AF	• 12 months • 12 months

			(AF)	Heartbeats application				
Dorje et al., 2019 [28]	Secondary	China	RCT among 321 patients with CHD	4-month intervention via WeChat	• Baseline assessment • Tobacco cessation • Exercise training • Physical activity counseling • Blood pressure management • Heart rate management • Disease knowledge • Medication adherence • Psychological management	• Standalone intervention • Social media platform WeChat coach	• Health outcomes • Lipid profile • Blood pressure • Exercise capacity • Nicotine dependence • Dietary habits • Weight • Quality of life	• 12 months • 6 months
Huo et al., 2019 [29]	Secondary	China	RCT among 502 patients with both CHD and diabetes mellitus	6-month text messages intervention	• Baseline assessment • Blood pressure management • Lipid management • Medication adherence • Physical activity counseling	• Standalone intervention • Researcher	• Blood pressure • Blood glucose • Lipid profile • Weight • Exercise capacity	• 6 months • 6 months
Perez et al., 2019 [30]	Primary	United States	Prospective randomized study 419297 among participants without AF	3-month smartphone application intervention	• Baseline assessment • Heart rate management	• Standalone intervention • Researcher	• Pulse	• 3 months • 3 months
Yousuf et al., 2019 [31]	Primary	Netherlands and United Kingdom	RCT among 402 people at risk for CVD	18-month email, e-Coaching intervention	• Baseline assessment • Blood pressure management • Lipid management • Weight management • Physical activity counseling • Diabetes management	• In-person session • Standalone intervention • Group session • Researcher	• Weight • Blood pressure • Blood glucose • Lipid profile • Quality of life • Exercise capacity • Dietary habits • Economic evaluation	• 6 months • 18 months
Zheng et al., 2019 [32]	Secondary	China	RTC among 822 patients with CHD	6-month text messages intervention of TEXT ME	• Baseline assessment • Disease knowledge • Medication adherence • Blood pressure management • Tobacco cessation • Exercise training • Physical activity counseling • Diabetes management •	• In-person session • Standalone intervention • Group session • Researcher	• Blood pressure • Weight • Nicotine dependence • Lipid profile • Exercise capacity	• 8 months • 6 months
Broers et al., 2020 [33]	Secondary	Spain and the Netherlands	RCT among 150 patients with CHD	3-month behavioral intervention eHealth program	• Baseline assessment • Exercise training • Physical activity counseling • Diabetes management	• Standalone intervention • Researcher	• Life style • Quality of life • Satisfaction • Intervention adherence	• 6 months • 3 months
Grau-Pellicer et al., 2020 [34]	Secondary	Spain	RCT among 41 patients with stroke	8-week intervention about digital platform based on mHealth applications	• Baseline assessment • Exercise training • Physical activity counseling	• Standalone intervention • Group session • Researcher	• Community ambulation • Sedentary behavior • Exercise capacity • Quality of life • Satisfaction	• 2 months • 2 months
Redfern et al., 2020 [35]	Secondary	Australia	RCT among 934 patients with or at risk of CVD	12-month Consumer Navigation of Electronic Cardiovascular Tools intervention	• Baseline assessment • Medication adherence • Disease knowledge • Exercise	• In-person session • Standalone intervention • Researcher, clinical staff	• Medication use • Blood pressure • Lipid profile • Nicotine dependence	• 12 months • 12 months

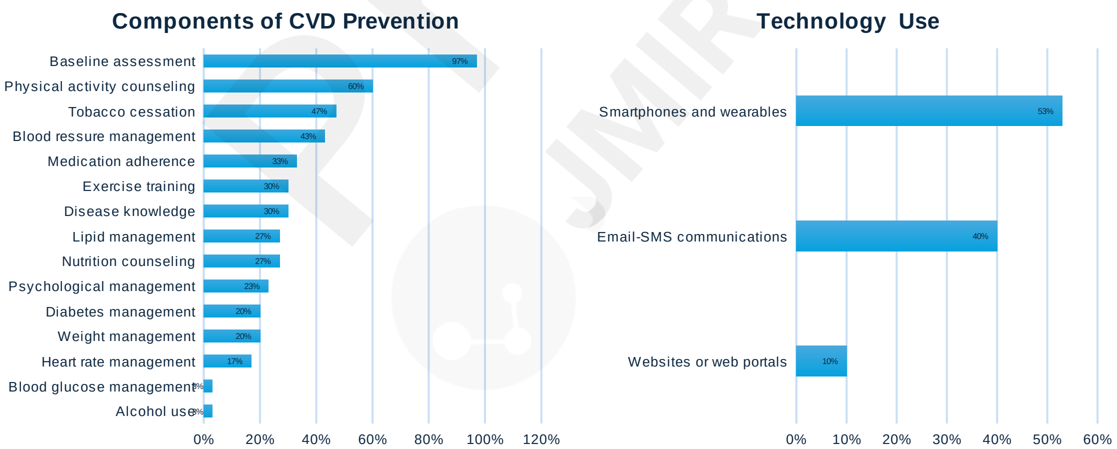
					• training • Physical activity counseling • Diabetes management • Tobacco cessation • Psychological management		• Weight • Exercise capacity • eHealth literacy • All-cause mortality	
Sengupta et al., 2020 [36]	Secondary	United States	Pilot study among 10 women	12-week intervention via smartphone and smartwatch on which the HerBeat application	• Baseline assessment • Exercise training • Heart rate management • Diabetes management • Psychological management	• Standalone intervention • Researcher, trained professional, health coach •	• Intervention adherence • Weight • Anxiety or depression	• 3 months • 3 months
Coorey et al., 2021 [37]	Secondary	Australia	RCT among 934 patients with CVD	12-month purpose-built, multi-feature web application intervention	• Baseline assessment • Nutrition counseling • Psychological management • Tobacco cessation • Physical activity counseling • Medication adherence • Disease knowledge	• In-person session • Standalone intervention • Nurses, dietitians, pharmacists	• Life style • eHealth literacy	• 12 months • 12 months
Kang et al., 2021 [38]	Secondary	Korea	RCT among 666 patients with clinical atherosclerotic CVD	6-month smartphone application intervention	• Baseline assessment • Blood pressure management • Physical activity counseling • Weight management • Medication adherence • Lipid management • Tobacco cessation	• Standalone intervention • Researcher, physician	• CVD Risk • Blood pressure • Lipid profile • Nicotine dependence • Diabetes status	• 12 months • 6 months
Muralidharan et al., 2021 [39]	Primary	India	RCT among 741 people with prediabetes and/or obesity	12-week intervention about mDiab application in smartphones and weekly health coach calls	• Baseline assessment • Blood pressure management • Physical activity counseling • Weight management • Lipid management • Tobacco cessation	• Standalone intervention • Group session • Researcher, coach	• Waist • Blood pressure	• 3 months • 3 months
Feldman et al., 2022 [40]	Secondary	United States	Observational study among 1802 patients with stroke	43-month medical history, Apple Watch wear patterns, and AF risk intervention	• Blood pressure management • Weight management • Heart rate management • Tobacco cessation • Alcohol use	• Standalone intervention • Group session • Researcher	• Medication use	• 43 months • 43 months
Sakakibara et al., 2022 [41]	Secondary	Canada	RCT among 126 patients within one-year post-stroke	12-month intervention about Stroke Coach and attention control Memory Training	• Baseline assessment • Physical activity counseling • Medication adherence • Blood pressure management • Lipid management	• Standalone intervention • Group session • Researcher, health professionals	• Life style • Quality of life • Cognitive status • Anxiety or depression	• 6 months • 6 months
Cheung et al., 2023 [42]	Secondary	Australia	RCT among 902 patients with type 2 diabetes or	6-month SMS text messages intervention	• Baseline assessment • Lipid managemen	• In-person session • Researcher	• Blood pressure • Lipid profile • Medication	• 6 months • 6 months

			CHD		t • Tobacco cessation • Physical activity counseling • Diabetes management		use • Engagement	
Li et al., 2023 [43]	Secondary	China	Nonrandomized trial among 243 patients with stroke	3-month smartphone mobile application intervention	• Baseline assessment • Disease knowledge • Medication adherence	• In-person session • Standalone intervention • Researcher	• Intervention adherence • Medication use	• 5 months • 3 months
Xu et al., 2023 [44]	Secondary	China	RCT among 108 patients with CHD	12-week smartphone-based gamification intervention	• Baseline assessment • Physical activity counseling • Psychological management	• Standalone intervention • Researcher	• Step count • Weight • Exercise capacity • Competence • Engagement	• 3 months • 3 months
Beckie et al., 2024 [45]	Secondary	United States	RCT among 47 women with CHD	3-month mHealth intervention with a smartphone, smartwatch, and health coach	• Baseline assessment • Physical activity counseling	• In-person session • Standalone intervention • Researcher	• Dietary habits • Anxiety or depression • Self-efficacy • Blood pressure • Health outcomes • Waist	• 3 months • 3 months

Table 1. Characteristics of the eligible studies

Items	Proportion
Research Type, n (%)	
RCT	24 (80)
Prospective randomized study	2 (7)
Pilot study	1 (3)
Nonrandomized trial	1 (3)
Observational study	1 (3)
Qualitative	1 (3)
Prevention type, n (%)	
Secondary	23 (77)
Primary	7 (23)
Location of study, by continent, n (%)	
America	19 (63)
Asia	8 (27)
Oceania	8 (27)
Europe	5 (17)
Publication year, n (%)	
2015-2019	17 (57)
2020-2024	13 (43)
Median of sample size (IQR)	465.5 (162.75-751.5)
Median of follow-up time (months; IQR)	6 (3.5-12)
Median of intervention duration (months; IQR)	6 (3-12)

Table 2. Summary of the eligible studies



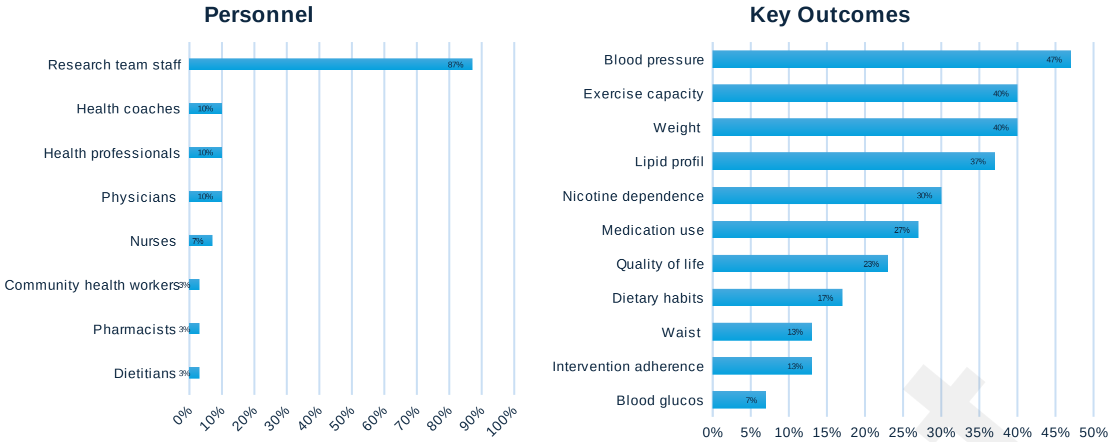


Figure 2. Percentage of eligible studies with components of CVD prevention, technology use, personnel, and key outcomes

Technology Use in Digital Solution

The analysis of 30 selected studies categorized the use of technology in digital health solutions for CVD prevention into three main categories: studies smartphones and wearables, email-SMS communications, and websites or web portals. Additionally, 1 study incorporated both email-SMS communications and websites or web portals.

More than half of the selected studies integrated smartphones or mobile devices with wearable technology for monitoring and managing patients' health conditions. Notable researchers including Johnston et al. [19], Morawski et al. (Morawski et al., 2018), Beratarrechea et al. [26], Brasier et al. [27], Dorje et al. [28], Perez et al., [30], Grau-Pellicer et al. [34], Sengupta et al., [36], Redfern et al. [35], Broers et al., [33], Kang et al. [38], Muralidharan et al. [39], and Li et al. [43] focused on the efficacy of smartphone applications in preventing CVD. For instance, Johnston et al. [19] evaluated an interactive patient support tool via a smartphone application designed to enhance treatment adherence and cardiovascular health among myocardial infarction patients. According to Grau-Pellicer et al. [34], they evaluated the effectiveness of a mHealth application on physical activity adherence, and suggested that this technology provides a way to promote adherence to home exercise programs post stroke. Sengupta et al. [36], Feldman et al. [40], and Beckie et al. [45] examined interventions that use smartphones and smartwatches to enhance CVD prevention. Xu et al. [44]explored the smartphone-based gamification intervention for CVD prevention. The use of email-SMS communications was also considerable, indicating the popularity of interventions such as the TEXT ME program [16,20,21,25,32]. In addition, the use of email or SMS programs [18,29,31], and SMS intervention [22,23,42], illustrated the various approaches employed in the field. There was relatively limited research on the use of websites or portals. Coorey et al. [37] introduced a purpose-built, versatile web-based application intervention. Sakakibara et al. [41] developed an attention control memory training program delivered via the web. Maddison et al., [17] took a multifaceted approach, integrating email-SMS communications and websites or portals into their interventions.

Key Outcomes

Across the 30 studies, the most common key findings are summarized in Table 3. We have distinguished between findings related to enhancing preventive behaviors and those related to monitoring health indicators for a more nuanced understanding of the results. For instance, blood pressure is categorized as a health indicator, whereas exercise capacity is categorized as a preventive behavior for CVD prevention. After the analysis of the key findings, it was found that individuals using digital solutions generally performed better when receiving interventions compared to individuals using traditional CVD prevention measures. For instance, due to reminders and personalized feedback, digital interventions promoted more consistent medication use [19,22,24,26,42,43]. Furthermore, as a result of the enhanced engagement and support provided by these technologies, the quality of life indicators of participants using digital solutions improved significantly [17,31,33,34,41]. Dietary habits had also improved substantially, with digital platforms often providing tailored nutrition advice and monitoring that was more effective than traditional measures [22,25,28,31,45]. Intervention adherence was notably higher, which could be attributed to the real-time feedback provided by digital tools [19,32,36,43]. Waist circumference also showed slight reduction among those using digital interventions [23,39,45].

Notably, the digital solution showed efficacy comparable to the traditional control group across outcomes, including nicotine dependence, blood pressure, blood sugar levels, exercise capacity, and weight management. For example, digital interventions had the same impact on nicotine dependence as traditional interventions, with nearly half of the studies showing a positive trend towards improving smoking habits [16,20,26,38], and the remaining half showing no significant change [19,22,28,32,35]. Similarly, blood pressure, blood glucose levels, exercise capacity, and weight management results were comparable to those of the traditional control group. However, the effectiveness of digital solutions varies when it came to lipid profiles. Of the 10 studies reviewed, 3 reported elevated high-density lipoprotein (HDL) levels in the intervention group [25,28,31,35]. 3 other studies showed reductions in low-density lipoprotein (LDL) and cholesterol levels [16,20,23]. No significant changes were observed in the remaining 4 studies [29,32,38,42].

Blood pressure (14/30, 47%) (health indicator)	**8 of the 14 studies reported that the digital solutions improved blood pressure management and was no worse than the control group [16,20,23,24,28,31,35,45]. In contrast, 6 studies concluded that it did not have a statistically significant influence on blood pressure management [18,29,32,38,39,42].**
Exercise capacity (12/30, 40%) (preventive behavior)	7 studies examined exercise capacity as outcomes showing that the performance of the intervention group was comparable to that of the control group [16,20,21,28,34,35,44]. Notably, in five of these studies, no significant difference in exercise capacity was observed [17,19,29,31,32].
Weight (12/30, 37%) (preventive behavior)	In 6 of the 11 studies, digital solutions were effective in addressing weight management [16,20,23,25,31,36,44]. However, 5 studies found no significant change or a slight decrease in body weight or BMI after the digital intervention [19,28,29,32,35].
Lipid profile (11/30, 37%) (health indicator)	3 of the 10 studies reported elevated HDL levels in the intervention group [25,28,31,35]. 3 other studies showed reductions in LDL and total cholesterol levels [16,20,23]. No significant changes were observed in the remaining 4 studies [29,32,38,42].
Nicotine dependence (9/30, 30%) (health indicator)	Of the 9 studies included, 4 showed a positive trend towards improvement in smoking habits, as evidenced by a reduction in nicotine dependence scores [16,20,26,38], while the remaining 5 did not change significantly [19,22,28,32,35].
Medication use (8/30, 27%) (preventive behavior)	6 studies found that medication use was beneficial and had a positive effect [19,22,24,26,42,43]. However, 2 studies reported slight or insignificant changes due to medication [35,40].
Quality of life (7/30, 23%) (preventive behavior)	5 studies documented an improvement in quality of life for participants in the

	intervention group [17,31,33,34,41]. Conversely, 2 studies failed to observe significant differences in quality of life [19,28].
Dietary habits (5/30, 17%) (preventive behavior)	Of the 5 studies reviewed, all reported improvements in dietary habits [22,25,28,31,45].
Intervention adherence (4/30, 13%) (preventive behavior)	4 studies provided evidence to support the idea that digital solutions can improve individuals' adherence to interventions [19,32,36,43].
Waist (4/30, 13%) (health indicator)	3 studies showed a slight reduction in waist circumference after the digital intervention [23,39,45]. However, there was also 1 study in which no significant effects were observed [18].
Blood glucose (2/30, 7%) (health indicator)	1 study showed the effectiveness of interventions in managing blood glucose levels [29]. In contrast, 1 study found no significant benefit in this regard [31].

Table 3. Summary of findings by thematic outcomes.

Study outcomes varied across follow-up times. Dietary habits and intervention adherence yielded positive results at various intervals, including 3, 6, and 12 months [22,25,28,31,45], as well as 3, 5, 6, and 8 months [19,32,36,43]. Waist circumference decreased at 3 months in studies by Beckie et al. [45], Jones et al. [23], and Muralidharan et al. [39], but Anand et al. [18] found no significant effects at 12 months. Quality of life was assessed at 6-month intervals [17,31,33,41] and at 2 months [34], with Johnston et al. [19] and Dorje et al. [28] finding no significant differences in digital intervention versus usual care groups at 6 and 12 months. Medication use improved health outcomes over 3, 5, 6, and 12 months [19,22,24,26,42,43], although Feldman et al. [40] and Redfern et al. [35] observed minimal changes over longer periods (12 and 43 months). Studies on nicotine dependence showed varied results, with some studies indicating positive trends over longer follow-ups [16,20,26,38], while others reported different outcomes [19,22,28,32,35]. Positive blood pressure outcomes were reported within 3 months by Beckie et al. [45], Jones et al. [23], and Morawski et al. [24], with improvements observed at 6 months by Chow et al. [16] and Yousuf et al. [31]. Dorje et al. [28] and Redfern et al. [20,35] noted significant benefits at 12 months, whereas Anand et al. [18], Kang et al. [38], and Cheung et al. [42] respectively found no significant impact at 12 and 6 months. Muralidharan et al. [39], Huo et al. [29], and Zheng et al. [32] did not observe notable improvements over 3, 6, and 8 months. Few studies exist on blood glucose levels, with Huo et al. [29] showing effectiveness at 6 months, but Yousuf et al. [31] found no significant benefits during the same period. For exercise capacity, positive findings were reported at 6 and 12 months by Chow et al. [16], Thakkar et al. [21], Dorje et al. [28] and Redfern et al. [20,35], with shorter follow-ups also supporting these findings. However, no significant differences were found between digital intervention and usual care groups at 6 or 8 months [17,19,29,31,32]. For weight management, significant reductions were noted at 6 and 12 months by Chow et al. [16] and Redfern et al. [20], while Jones et al. [23] and Sengupta et al. [36] reported favorable outcomes at 3 months. However, minimal to no improvements were found by Dorje et al. [28] and Huo et al. [29] at 6 months. Johnston et al. [19] and Redfern et al. [35] also showed no significant changes at 6 and 12 months, respectively. Studies with 3 to 6-month follow-ups predominantly showed no significant changes in lipid profiles, with minimal impacts observed within 6 months [23,25,42]. Conversely, longer follow-ups tended to show more pronounced effects, such as significant increases in HDL reported by Dorje et al. [28] and Redfern et al. [35] and reductions in LDL and total cholesterol observed by Redfern et al. [20] and Chow et al. [16]. However, Huo et al. [29] and Kang et al. [38] found no significant lipid changes in long-term studies.

The review examined the comprehensive standalone interventions and found that the interventions in 7 studies identified as standalone included 5 components or more for CVD prevention, excluding baseline assessments [25,28,31,32,35,38,39]. Outcomes associated with most of the key outcomes associated with the prevention of CVD components were heterogeneous through the intervention. Among these 7 studies, Redfern et al. [35] documented outcomes regarding medication use, showing no significant effects. Regarding blood glucose, Yousuf et al. [31] did not find a significant benefit. With regard to waist circumference, Muralidharan et al. [39] demonstrated a reduction in waist circumference after digital intervention. Santo et al. [25], Dorje et al. [28], and Yousuf et al. [31] observed improvements in mood within the intervention group, while Redfern et al. [35] found similar results. Nevertheless, Kang et al. [38] and Zheng et al. [32] discovered that the digital solutions did not significantly impact lipid profiles. Regarding weight management, Santo et al. [25], Yousuf et al. [31], and Redfern et al. [35] observed that digital solutions were effective. In contrast, Dorje et al. [28] and Zheng et al. [32] reported that there was no significant change, or even a slight decrease, in body weight or body mass index (BMI) after the digital intervention. Santo et al. [25], Dorje et al. [28], and Yousuf et al. [31] all recorded improvements in dietary habits. Dorje et al. [28], Yousuf et al. [31], Redfern et al. [35], and Muralidharan et al. [39] reported that the digital solution significantly enhanced blood pressure management and was no worse than the control group. However, Kang et al. [38] found that digital solutions did not significantly affect blood pressure management. In terms of exercise capacity, Dorje et al. [28] and Redfern et al. [35] showed that the intervention group was similar to the control group. Yousuf et al. [31] and Zheng et al. [32] discovered that there was no difference in exercise capacity between the digital intervention group and the control group. For nicotine dependence, Kang et al. [38] showed a positive trend towards improving smoking habits, while Dorje et al. [28], Zheng et al. [32], and Redfern et al. [35] showed no significant change. In terms of quality of life, Yousuf et al. [31] reported an enhanced quality of life, while Dorje et al. [28] reported no significant difference in quality of life of intervention groups. Overall, interventions taken and reported outcomes varied.

Discussion

The Role of Digital Solution for CVD Prevention

The study highlights the potential of digital technologies to enhance healthcare delivery and expand CVD prevention by enhancing preventive behaviors and monitoring health indicators. These digital solutions can significantly improve individual outcomes and facilitate the wider implementation of preventive approaches. Unlike previous systematic reviews, which often focused narrowly on specific aspects of digital health, our study provides a comprehensive assessment of digital solutions, including primary and secondary prevention of CVD. Our analysis of the current studies reveals the diverse effectiveness of various digital solutions. This study is based on a body of existing studies that endorses remote CVD prevention using Internet-based platforms and digital devices. These technologies can provide innovative ways to monitor, educate, and engage individuals. Our findings show that using digital solutions to prevent CVD are both feasible and effective, and the results are comparable to traditional approaches. Whether as a complement or substitute for traditional approaches, digital solutions show great potential in improving individual health outcomes [16,19,21–29,32–34,39,43–45]. Notably, the integration of digital technologies into CVD prevention can make more efficient use of healthcare resources, reduce the burden on healthcare systems, and provide cost-effective solutions for individuals [17,31].

The results of our review are consistent with previous studies, including Gray et al. [46], which demonstrated the effectiveness of remote consultation, smartphone applications, wearables, remote monitoring, and predictive analytics in influencing individual behavior. These digital solutions can greatly contribute to the primary and secondary prevention of CVD and play a role in preventing and managing disease. In addition, Moshawrab et al. [47] showed that wearable device was highly accurate in detecting, predicting, and even treating CVD. Their study highlighted the potential of digital health solutions to improve individual outcomes and optimize the use of healthcare resources, further supporting their integration into standard CVD prevention strategies. Our review and included studies highlight the role of communication strategies and digital literacy in digital health solutions to prevent CVD. Effective communication tactics can actually have an impact towards the overall success of these solutions. Strategies such as increasing engagement, enhancing adherence, providing support, offering personalized experiences, and implementing feedback mechanisms can motivate individuals to actively participate in and commit to their preventive behaviors. Effective communication can encourage sustained health outcomes between healthcare providers and individuals by fostering a supportive environment. Moreover, individuals at risk of CVD must have the necessary skills to use these digital health tools effectively. Without adequate digital literacy, the potential benefits of remote consultations, smartphone applications, wearables, and remote monitoring systems cannot be fully realized, as the digital divide is characterized by some individuals having limited access to digital skills, which creates barriers to the effective use of digital health solutions [48]. Improving digital literacy can greatly improve the ability to address CVD prevention by setting baselines, customizing treatment plans, tracking progress, and using technology to address individual challenges through targeted support, especially for older people.

Future Research Recommendations

Some limitations appeared in our review. First, although this review aimed to address the effects and factors surrounding specific phenomena, we did not use meta-analysis methods to summarize empirical evidence due to the heterogeneity of the studies. The reviewed articles exhibited significant variation in study designs, main outcomes, technologies, and control groups. For instance, some studies focused on a single digital health intervention, such as a mobile health application, while others looked at a combination or multiple uses of various digital technologies. In addition, when considering control groups, some studies used standard care in people with traditional CVD prevention, while others did not include control groups. Second, our review is limited by its time frame. While we included relevant papers published between 2000 and 2024, the earliest studies that met our inclusion criteria were from 2015. This might due to that digital solutions for disease prevention are a relatively new field that has emerged with advances in technology in recent years. Third, our review only highlighted primary and secondary prevention of CVD. However, tertiary prevention, which involved advanced medical procedures and interventions aimed at managing and mitigating the long-term effects of diagnosed CVD, also played a role in the integrated management of CVD. Therefore, we suggested several strategies for future research. First, the objectives of digital solutions must be clearly defined, clearly stating whether they are intended as comprehensive standalone programs or as a complement to traditional prevention approaches. Second, detail the specific CVD prevention components targeted by the intervention, including the relevant technology or equipment used. Third, incorporate the results of digital solutions on user engagement and behavior modification using validated metrics such as compliance rates, user satisfaction surveys, and long-term health outcomes. Fourth, explore the cost-effectiveness of implementing digital solutions to prevent CVD, including tertiary prevention, compared to traditional approaches. May consider factors such as scalability, maintenance, and initial setup costs.

We have identified several key aspects for future research in the field of digital interventions for CVD prevention. Firstly, while digital solutions effectively address factors such as eating habits, interventions targeting other risk factors, including blood glucose control, are still lacking. Moreover, further evaluation is needed to assess the ongoing efficacy of these digital solutions, so studies using larger population and implementing suitable control groups are needed [8,49]. Secondly, future research should focus on integrating multifaceted interventions to address a wide range of CVD risk factors, including stress management. It is crucial to study the synergies of combining digital tools such as mobile applications, wearables and telemedicine. Understanding the psychological and behavioral mechanisms behind user engagement, such as motivation, digital literacy, and personalization, is also critical to improving adherence and sustained behavior change [50]. Thirdly, it is also crucial to evaluate the incidence of adverse events among individuals undergoing these interventions compared to traditional methods [15]. Rigorous monitoring and reporting of adverse events will provide insight into the potential risks associated with these technologies, helping to refine protocols and ensure individual safety. Lastly, exploring the potential of artificial intelligence (AI) to improve communication effectiveness by personalizing and tailoring interventions in real time could significantly improve user experience [51,52]. As an emerging field, AI has shown great potential in fields such as health care and education. In the field of CVD prevention, its ability to analyze large data sets, predict individual outcomes, and tailor interventions to individual health conditions holds great potential for strengthening prevention measures and optimizing patient care pathways [51–53]. As research in this field continues to advance, the integration of AI into clinical practice could lead to more effective, personalized and accessible solutions to combat CVD worldwide.

Conclusions

Our study highlights the potential of digital technologies to alleviate challenges associated with traditional CVD prevention approaches by enhancing preventive behaviors and monitoring health indicators. The widespread implementation of digital solutions in CVD prevention is expected to have a significant impact, increasing accessibility, affordability, cost-effectiveness, and improving individual outcomes beyond what can be achieved with traditional approaches. However, interventions evaluated focused primarily on medication use, quality of life, dietary habits, intervention adherence, and waist circumference, with limited attention to other components of CVD prevention. In addition, our study primarily assessed the technical aspects and comprehensiveness of digital procedures in the prevention of CVD. However, the complexities associated with certification of CVD prevention programs are beyond the scope of this review. Future studies should aim to explore more comprehensive CVD prevention interventions to assess their long-term and sustained impact.

Conflicts of Interest

There are no conflicts of interest in this work.

Abbreviations

AF: atrial fibrillation
AI: artificial intelligence
BMI: body mass index
CHD: coronary heart disease
CVD: cardiovascular disease
HDL: high-density lipoprotein
LDL: low density lipoprotein
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial
SMS: short message service
TEXT ME: tobacco, exercise and diet messages

Multimedia Appendix 1

Multimedia Appendix 2

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