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SYSTEMATIC REVIEW

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Text messages as a tool to improve cardiovascular disease risk factors control: a systematic review and meta-analysis of randomized clinical trials

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Abstract

Background Cardiovascular diseases (CVDs) are the leading cause of global mortality, claiming 17.9 million lives annually. Major risk factors include unhealthy diets, physical inactivity, tobacco use, and excessive alcohol consumption. Text messaging interventions have the potential to improve individual risk factors and encourage healthy habits. These interventions have been shown to help manage risk factors and slow disease progression. This systematic review and meta-analysis aimed to evaluate the efficacy of text messaging interventions for the primary prevention of CVD risk factors.

Methods This review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Searches were conducted on PubMed, MEDLINE, Cochrane, Scopus, Web of Science, Embase, and CINAHL using MeSH and free-text terms related to cardiovascular disease and text messaging interventions on February 12, 2024.

Results Out of 5,748 identified articles, 22 studies met the inclusion criteria. The meta-analysis revealed that text messaging interventions significantly improved medication adherence, with a pooled effect size (Mean Difference [MD]) of 0.62 (95% CI: 0.37 to 0.86; $p < 0.01$; $I^2 = 0.0\%$). They also significantly reduced diastolic blood pressure (MD: -2.66; 95% CI: -4.63 to -0.70; $I^2 = 85\%$; $p < 0.01$) and systolic blood pressure (MD: -6.12; 95% CI: -10.26 to -1.97; $I^2 = 96\%$; $p < 0.01$). However, no significant improvements were observed in BMI, LDL, HDL, total cholesterol, or HbA1c levels.

Conclusion Text messaging interventions effectively improve medication adherence and reduce blood pressure, making them a promising tool for CVD risk control. However, their impact on other cardiovascular risk factors is limited, highlighting the need for further research to explore long-term effects and personalized interventions for diverse populations. Integrating these digital tools into healthcare strategies could enhance CVD prevention efforts and improve cardiovascular risk factor control outcomes.

Keywords Text messages, Cardiovascular, Risk factorsMeta-analysis, Systematic review

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Introduction

Cardiovascular diseases (CVDs) remain the leading cause of global mortality, claiming 17.9 million lives annually [1]. They encompass a spectrum of heart and blood vessel disorders, with heart attacks and strokes alone responsible for over 80% of these deaths, which occur prematurely in individuals under 70 [1]. Major behavioral risk factors contributing to CVDs include unhealthy diets, physical inactivity, tobacco use, and excessive alcohol consumption. These behaviors are associated with elevated blood pressure, glucose levels, lipids, and obesity, all of which significantly increase susceptibility to heart attacks, strokes, and related complications [1, 2].

CVD incidence is growing among younger adults [3, 4]. This trend could be attributed to the rising rates of uncontrolled CVD risk factors, such as obesity, smoking, lack of exercise, and poor medication adherence, among others [5]. Therefore, there is a need for novel strategies to control CVD risk factors.

Recent research has focused on using text messages for health purposes, which enable the dissemination of information in near-real time to thousands of recipients as standardized bulk messages or personalized, tailored messages [6]. Text messaging intervention strategies have proven effective in controlling risk factors and slowing disease progression, including diabetes, where they serve as a low-cost and effective tool for individuals with impaired glucose levels [7].

In the CVD context, although drug interventions are cost-effective in managing and reducing the risk of recurrent cardiovascular events, medication adherence remains suboptimal. As a scalable and cost-effective tool, mobile phone text messaging offers an opportunity to convey health information, deliver electronic reminders, and encourage behavior change [8]. Text messaging interventions have the potential to successfully improve individual risk factors and promote healthy habits. Previous studies have demonstrated the efficacy of these interventions in controlling risk factors, although the results have varied across different risk factors [9–12].

This systematic review and meta-analysis aimed to evaluate the efficacy of text messaging as a strategy to control CVD risk factors.

Methods

The present study employed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines [13] to ensure a comprehensive and systematic approach to our review. The protocol for this review has been registered in the PROSPERO database under the following ID: CRD42024529187.

Criteria for considering studies in this review

Types of participants

This study set specific participant selection criteria, including all participants aged 18 and older who were diagnosed with cardiovascular disease or identified as having one or more cardiovascular risk factors, such as hypertension, hyperlipidemia, diabetes mellitus, obesity, physical inactivity, nonadherence to prescribed medication, or a history of smoking. Exclusion criteria included studies assessing multiple modalities and studies involving teenagers and children.

Types of intervention

The interventions included in this analysis were limited to text messages aimed at controlling cardiovascular disease risk factors via a text messaging service. The control group consisted of participants who did not use the text messaging service. Studies assessing other modalities (e.g., websites, email, apps, video, web portals, phone calls) without a specific text message and control group were excluded.

Outcomes

The outcomes measured included studies reporting the effectiveness of text messaging interventions for cardiovascular risk factor control. Studies not reporting relevant outcomes were excluded. Effectiveness was assessed using mean differences (MD). When these values were not reported, they were manually calculated using information provided by the authors. This review focused specifically on the impact of text messages on improving CVD-related factors, such as smoking cessation, HbA1c levels, diastolic blood pressure (DBP), systolic blood pressure (SBP), body mass index (BMI), cholesterol levels, low-density lipoprotein (LDL) levels, high-density lipoprotein (HDL) levels, medication adherence, and exercise.

Types of study

This research systematically reviewed relevant studies published from 2000 to 2023 in English. Only randomized clinical trials (RCTs) were included to minimize heterogeneity across studies, establish causal relationships between interventions and outcomes, and reduce bias. Excluded materials included case series, cohort studies, case-control studies, cross-sectional studies, dissertations, book chapters, protocol articles, reviews, news articles, conference abstracts, letters to the editor, editorials, commentaries, systematic reviews, and meta-analyses. Additionally, studies that did not clearly describe their methods, were duplicates, or failed to provide necessary data or respond to queries from the original authors were excluded.

Searching methods

A systematic search was conducted on December 2, 2024, across multiple databases, including PubMed, MEDLINE, Cochrane, Scopus, Web of Science, Embase, and CINAHL. The search strategy utilized Medical Subject Headings (MeSH) terms and free-text terms such as "cardiovascular disease," "text messaging," "prevention," "cellular phone," and "risk reduction behavior." Full search strategies for each database are detailed in the supplementary material (Supplementary Tables 1–6). The PRISMA flowchart [13] was used to guide the systematic review article selection process, resulting in a uniform dataset and enhancing the accuracy and reliability of our findings.

Selection of studies

An initial screening based on titles and abstracts was conducted by two reviewers (AK, SM), who independently selected trials for inclusion using predetermined inclusion and exclusion criteria. Rayyan (8) was used for data extraction, and duplicates were filtered. Disagreements about study inclusion were resolved through consensus and consultation with a third reviewer (JVSO). Subsequently, a full-text analysis was conducted by two reviewers (LS, VA), with a third reviewer (SZS) resolving any disagreements.

Assessment of risk of bias in included studies

The risk of bias was evaluated using criteria outlined in the Cochrane Handbook [14]. The Cochrane RoB 2.0 tool (10) was applied to assess the quality of RCTs included in the systematic review. Two independent reviewers (AK, JVSO) evaluated the risk of bias for each study, with discrepancies resolved through discussion with a third, blinded reviewer (ECM).

Statistical analysis

A meta-analysis was conducted only when two or more studies reported a given outcome, following the guidelines of the Cochrane Handbook. Statistical analyses were performed using R Software version 3.6.0 to calculate effect sizes [15]. Effect sizes were presented as mean differences with 95% confidence intervals (CI). A random-effects model was used to account for heterogeneity among study statistics. Substantial and considerable heterogeneity were indicated by $I^2 \geq 50\%$ and $\geq 75\%$, respectively [16]. A study removal method was employed to perform sub-analyses and assess whether individual studies influenced the overall effect size. A p-value of < 0.05 was considered statistically significant.

Results

Across the database, we identified a total of 5,748 possible articles. After a thorough examination, 17 duplicate articles were removed before screening. A total of 5,731 articles were reviewed during the screening process, and 5,690 were excluded. From the remaining articles, 41 were sought for retrieval, but four reports were not retrieved. Of the 37 reports assessed for eligibility, 15 were excluded due to the wrong study design. Ultimately, 22 studies were included in the final review process. This process is summarized in the PRISMA Flowchart (Fig. 1).

Study characteristics

The study characteristics encompass a comprehensive evaluation of text messaging interventions as a tool for cardiovascular risk factor control, including cholesterol levels, medication adherence, physical activity, BMI, SBP, DBP, smoking, LDL levels, HDL levels, and HbA1c. The research was conducted across a diverse range of countries, such as the United Kingdom (12%), Canada (5%), Pakistan (5%), Iran (10%), Australia (22%), China (10%), New Zealand (10%), Nepal (5%), Italy (5%), the United States (10%), Brazil (5%), and Turkey (5%), indicating a broad geographic representation. Each study utilized different types of SMS interventions, ranging from one-way to two-way messaging, with varying frequencies (daily, weekly, etc.) and durations (ranging from weeks to a year). The SMS content in our included studies (see Table 1) focuses on increasing awareness about cardiovascular health, encouraging lifestyle changes, promoting adherence to treatments, and providing reminders for clinic visits through personalized and educational support. Most studies (61%) reported a positive impact of these interventions on cardiovascular risk factor control, with significant improvements in medication adherence (34% of studies), increased physical activity (28% of studies), and notable reductions in SBP and DBP (51% of studies). Studies reported varied outcomes, often focusing on blood pressure, physical activity, and medication adherence.

Regarding SBP and DBP, blood pressure readings were reported as averages at two specific time points: at baseline (before the intervention) and at the end of the intervention. Only two studies reported BP averages at multiple time points during the follow-up period. In these studies, we used the BP measurement from the final follow-up time point in our analysis. The remaining studies reported BP averages at baseline and at the end of the intervention, and these values were used for

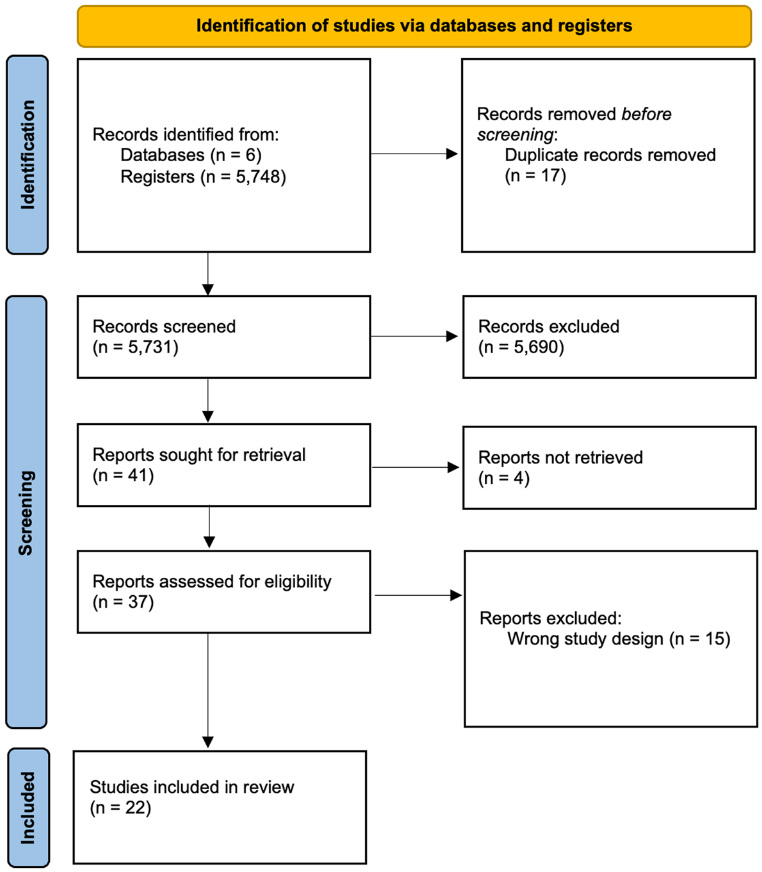

Fig. 1 PRISMA flow diagram. Prisma Flow Diagram delineates the systematic process of identifying and screening studies across multiple databases, culminating in selecting 22 studies

the analysis. Tam H [9] in China and Bhandari B [22] in Nepal observed reductions in SBP, while Bobrow K [35] in South Africa found only a small reduction in SBP control. Chow C [21] reported significant reductions in SBP, LDL levels, and BMI in Australia. However, Kes D [29] in Turkey observed lower BP levels, while Golshahi J [34] in Iran and Chow C [28] in Australia reported no significant effects on BP or lifestyle changes. Smoking outcomes were reported in four studies. Chow C [21] and Kiselev A [33] found a significant smoking reduction in the intervention group in Australia and Russia. In contrast, Santo K [30] and Chow C [28], both from Australia, found no significant differences between interventions and the control group.

Medication adherence was a key outcome in multiple studies. Kamal A [11] in Pakistan, Khonsari S [20] in Malaysia, Dale L [27] in New Zealand, and Kes D [29] in Turkey all reported improved adherence. In contrast, studies by Chow C [28] in Australia and Santo K [30] found no significant differences in adherence. Physical activity improvements were noted by Dale L [18] in New Zealand, Foccardi G [23] in Italy, and Klimis H [12] in Australia, with sustained fitness gains observed by Duscha B [31] in the USA. Song Y [32] reported that exercise tolerance in China improved. Other notable outcomes include improved medication self-efficacy, as found by Park L [25] in the USA, while Wald D [26] in the UK highlighted enhanced medication adherence in patients on cardiovascular treatments. Kiselev A [33] in Russia found improved health outcomes, whereas Golshahi J [34] in Iran saw no significant impact on lifestyle changes or hypertension control. Smoking outcomes were found in four studies. Chow C [21] and Kiselev A [33] found a significant smoking reduction in the intervention group in Australia and Russia. In contrast, Santo K [30] and Chow C [28], both in Australia, did not find significant differences between interventions and the control group. All findings are summarized in Table 1 [9, 11, 12, 17–30].

Risk of bias assessment

This risk of bias assessment utilized Cochrane's Risk of Bias 2.0 tool for randomized controlled trials to evaluate the quality or risk of bias in the included studies.

Table 1 Included studies in systematic review: intervention outcomes and key points

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Kamal a, 2015 [11]	Pakistan	Intervention: 56; Comparator: 57.6	326	2 months	Medication reminders and education	Two-way text messaging	76	Reminder to medication = Daily; Health information = Twice a week	SMS reminders plus health information SMS	SMS reminders on medication	Usual care	Not specified	There is no statistically significant difference noted between groups, but clinically, medication adherence improved in stroke patients.
Anand S, 2016 [17]	Canada	Control: 50.6 (10.9); Cases: 50.6 (12)	343	12 months	Motivational messages and health tips	One-way text messaging	54	Weekly	(1) Stages of change–oriented motivational messages supporting confidence in behavior change. (2) Health tips messages focused on diet and physical activity.	Digital health intervention focused on improving diet and physical activity to reduce MI risk	Usual care	Automated system	No significant difference in myocardial infarction (MI) risk score change was observed. Additionally, knowing genetic risk status at baseline did not affect the MI risk score change.
Dale L, 2015a [18]	New Zealand	Control: 59.9 (11.8); Intervention: 59 (10.5)	123	6 months	Comprehensive cardiac rehabilitation program	Two-way text messaging	168	Daily for the first 12 weeks; 5 times per week for the next 12 weeks	Lifestyle changes including stopping smoking, limiting alcohol consumption to less than 14 units per week, eating 5 servings of fruits and vegetables daily, and maintaining physical activity.	Personalized program framed in social cognitive theory to improve adherence to recommended lifestyle behaviors	Usual care	Automated system	Text-messaging intervention helped to increase physical activity.

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Sadeghioan S, 2017 [19]	Iran	Intervention: 41.99 (0.17); Control: 40.15 (12.42)	3600	2 weeks	Cognitive learning, affective learning, psychomotor-based approach text	One-way text messaging	15	Every 2 weeks	SMS targeted cognitive and affective learning and advised checking blood cholesterol levels if not done in the past 12 months.	SMS reminders on cholesterol screening	Usual care	Tehran Heart Center	SMS improved adherence to preventive programs; female participants were more likely to check cholesterol levels than males.
Tam H, 2023 [9]	China	Control: 67.97 (9.5); Cases: 66.82 (10.5)	69	3 months	Motivational messages and health tips	One-way text messaging	12	Weekly	Educational program based on the Health Promotion Model, including health education sessions, leaflets, and text messages on hypertension management.	Text messages to improve hypertension management adherence behaviors	Usual care	Automated system	Text messages produced small-to-moderate effects on SBP and pulse pressure, with minimal effects on other outcomes.
Khonsari S, 2014 [20]	Malaysia	Total: 57.9 (12.64)	62	2 months	Medication reminders	One-way text messaging	Not specified	Before every medication intake	Text-message reminders for medication adherence and reminders to refill cardiac medications at the hospital.	Automated SMS reminders for medication adherence	Usual care	Automated system	Intervention group had significantly higher medication adherence than the usual care group.
Chow C, 2015 [21]	Australia	Control: 57.3 (9.3); Cases: 57.9 (9.1)	710	6 months	Lifestyle text messages	One-way text messaging	96	4 per week	Providing advice, motivation, and information that aimed to improve diet, increase physical activity, and encourage smoking cessation (if relevant).	Support for lifestyle changes (non-interactive)	Usual care	Automated system	LDL level, SBP, smoking, and BMI were all significantly lower in the intervention group compared with the control group.

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Bhandari B, 2022 [22]	Nepal	Total: 50.5	200	3 months	Medication reminders and education	One-way text messaging	36	3 times per week	General patient educational information (hypertension and its treatment, complications, signs and symptoms, medication, common side effects and consequences of non-adherence, physical activity, diet low in salt, low fat, and some cultural messages) and reminders for taking medication. Smoking- and alcohol-related messages were tailored according to each patient.	Text messages on hypertension management, medication adherence, and lifestyle advice	Usual care	Automated system	The intervention group yielded substantial reductions in both SBP and DBP, improvements in medication adherence, self-efficacy concerning medication management, and knowledge about hypertension.

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Foccardi G, 2021 [23]	Italy	Control: 61.1 (10.6); Cases: 61.4 (8.9)	32	3 months	Physical activity reminder	One-way text messaging	90	Daily	To perform the assigned exercise prescription.	Text reminders to maintain physical activity	Usual care	Not specified	The intervention group had an increase in moderate physical activity and reduced sedentary time compared to the control group. Additionally, showed improvements in heart rate, blood pressure, and exercise performance ($p < 0.05$).
Byrne J, 2020 [24]	UK	Control: 63.9 (6.9); Cases: 63.9 (SD 7.5)	212	12 months	Medication reminders and motivational messages	Two-way text messaging	44	Daily medication reminders; lifestyle advice	Medication reminders to take statins, as well as information, advice, and motivation to improve diet, increase physical activity, and encourage smoking cessation (if relevant).	Text reminders to take medication and lifestyle advice	Usual care	Automated system	The intervention group showed improvements in DBP ($p = 0.002$) and waist circumference ($p = 0.012$), along with greater perceived control of treatment and understanding of the condition.
Park L, 2014 [25]	USA	Intervention: 58.2 (SD 10.6); Education: 58.3 (SD 8.5); No TM: 61.1 (SD 9.1)	90	1 month	Medication reminders and education	Two-way text messaging	42	Daily medication reminders; 3 health messages per week	TM reminders to take antiplatelet and statin medications for 30 days after hospitalization.	Text messages for medication adherence and health education	Usual care	Automated system	Medication self-efficacy improved over 30 days; however, there was no significant difference in this improvement of the different groups ($p = 0.64$).

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Wald D, 2014 [26]	UK	Total: 60 (54–68)	303	6 months	Medication reminders	Two-way text messaging	44	Daily for 2 weeks, then alternate days for 2 weeks, then weekly for 22 weeks	Text messages content were customized so each patient received the text just after the time they were advised to take their medication.	Text reminders to take medication and asking patients to reply if they had taken their medication.	Usual care	Automated system	Among patients taking blood pressure and/or lipid-lowering treatment for the prevention of cardiovascular disease events, text messaging improved the extent to which patients took their prescribed medication.
Dale L, 2015b [27]	New Zealand	Control: 63.7 (7.44); Cases: 61.38 (8.98)	171	6 months	Exercise prescription and behavior change	One-way text messaging	27	Weekly	Exercise prescription tailored to participants' baseline fitness level and behavior change strategies framed in social cognitive theory.	Theory-based, automated package of exercise prescription and behavior change text messages and a supporting website.	Usual care	Automated system	The intervention group reported significantly greater medication adherence, and most intervention participants reported reading all their text messages.
Klimis H, 2021 [12]	Australia	Control: 58.7 (11); Cases: 58.5 (10.4)	246	6 months	Motivational and supportive messages	One-way text messaging	100	4 messages per week	Message content covered: diet, physical activity, smoking (if applicable), medication adherence (if applicable), and general cardiovascular health relevant to primary prevention.	Motivational and supportive messages on diet, physical activity, smoking, general cardiovascular health, and medication adherence.	Usual care	Automated system	Intervention participants were less likely to be physically inactive, but there were no significant changes in other single cardiovascular risk factors (CVRF).

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Chow C, 2022 [28]	Australia	Control: 58 (10.9); Cases: 58 (10.4)	1424	12 months	Motivational and supportive messages	Two-way text messaging	192	4 messages per week for 6 months, 3 messages per week for 6 months	One-third of the bank of messages were on lifestyle (diet, exercise, and smoking if relevant), another one-third of messages were on cardiovascular secondary preventative medications, and the remaining one-third of messages were on general secondary prevention topics (BP or cholesterol targets, mental health, places and services providing help, and barriers to and facilitators of medication adherence).	Motivational and supportive messages on medications and healthy lifestyle with the opportunity for 2-way communication (text or telephone)	Usual care	Automated system	No difference was found between intervention and control groups at 12 months in adherence to individual medications, SBP, LDL level, cholesterol, smoking, or exercising regularly.

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Kes D, 2021 [29]	Turkey	Control: 52.2 (6.2); Intervention: 54.9 (6.6)	77	3 months	Medication reminders and education	One-way text messaging	154	2 messages per week for 12 weeks	Personalized text messages that remind to take prescribed medication containing participants' names, medication name, dosage, and time. Informational SMSs also contained general information on hypertension and BP measurement and recording.	Nurse-led telephone support and SMS reminders for medication adherence and BP control	Usual care	Nurse-led	Medication adherence was found to be significantly higher in the intervention group. Mean SBP and DBP were statistically significantly lower in the intervention group than in the control group.
Santo K, 2018 [30]	Australia	Control: 57.2 (9.64); Cases: 57.9 (8.77)	710	6 months	Lifestyle text messages	One-way text messaging	96	Four messages per week	Provide general healthy eating tips and motivate patients to eat more fruits and vegetables, increase fish intake, decrease unhealthy fat use, and decrease the levels of salt consumption in their diet.	Motivational reminders and advice on diet and lifestyle	Usual care	Not specified	There were no significant differences on adherence to ≥4 dietary guideline recommendations across the subgroups tested (by age, sex, education, BMI, smoking, and cardiac rehabilitation attendance).

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Duscha, B, 2018 [31]	USA	Controls: 66.5 (7.2); Cases: 59.9 (8.1)	25	3 months	Exercise and health coaching	Two-way text messaging	12	Weekly	Exercise prescription by daily step count based on their last two weeks of Cardiac Rehabilitation. In addition, patients received health coaching for the duration of the study.	Program using physical activity trackers and health coaching following CR graduation	Usual care	Not specified	A 12-week mHealth program sustained the gains in peak VO2 and physical activity achieved by site-based CR. Usual care group showed a decrease in physical activity and fitness.
Song Y, 2019 [32]	China	Controls: 54.8 (9.13); Cases: 54.17 (8.76)	96	6 months	Exercise prescription and feedback	Two-way text messaging	27	Weekly	Exercise prescription and weekly feedback on exercise performance.	Telemonitored exercise rehabilitation	Usual care	Automated system	Telemonitored exercise rehabilitation significantly improved exercise tolerance and compliance.
Kiselev A, 2012 [33]	Russia	Control: 51 (11); Intervention: 49 (11)	199	12 months	Medication reminders and Lifestyle focused support	Two-way text messaging	365	Reminder to medication = Daily; Health/lifestyle information = Weekly	Home BP monitoring, treatment, correction of BMI, smoking; collection of data on BP, BMI, and number of cigarettes smoked.	SMS reminders, scheduling visit	Usual care	Automated system	Automated SMS improved medication adherence and health outcomes like reduction of smoking in participants compared to usual care.
Golshahi J, 2015 [34]	Iran	Control: 57.51 (8.5); Intervention: 56.76 (8.9)	90	6 months	Lifestyle text messages	One-way text messaging	27	Weekly	Maintain physical activity, diet, and stop smoking.	Text reminders	Usual care	Not specified	SMS could not affect favorably on lifestyle changes and hypertension control.

Table 1 (continued)

Author and Year	Country	Age mean (SD)	Sample Size (total)	Time of Intervention	Type of SMS	Type of Transmission	Total Number of SMS per Person	Frequency of SMS	SMS Content	Intervention	Control	Who Sent the Message	Result
Bobrow K, 2014 [35]	South Africa	Control: 54.7 (11.6); Intervention: 53.9 (11.2)	914	12 months	Informational and interactive	Two-way text messaging	54	Weekly	Messages to motivate collecting and taking medicines, and to provide education about hypertension and its treatment. Additional reminders were sent when medicines were ready for collection or about scheduled clinic appointments.	Written information about hypertension and healthy living	Usual care	Not specified	A small reduction in SBP control was found in SMS group compared with usual care at 12 months.

MI Myocardial Infarction, *SMS* Short Message Service, *SBP* Systolic Blood Pressure, *DBP* Diastolic Blood Pressure, *LDL* Low-Density Lipoprotein, *BMI* Body Mass Index, *CVRF* Cardiovascular Risk Factor, *BP* Blood Pressure, *mHealth* mobile health, *VO2* maximal oxygen consumption, *CR* Cardiac Rehabilitation

As summarized in the figure, 12 articles (55%) indicated some concerns, while the remaining 10 (45%) demonstrated a low risk of bias. The overall results are depicted in three colors: green for low risk, yellow for some concerns, and red for high risk. Notably, none of the articles (0%) fell into the high-risk category. This information is presented in Fig. 2.

Meta-analysis results

Medication adherence (Morisky score)

The random-effects model synthesized the MD across the studies, considering variability within and between studies. The analysis included two studies with 323 observations: 161 in the experimental group and 162 in the control group. The pooled effect size was MD 0.62 (95% CI: 0.37 to 0.86; $p<0.01$, $I^2 = 0.0\%$), indicating a statistically significant improvement in medication adherence measured by the Morisky score in the experimental group compared to the control group (Fig. 3). Due to the limited number of studies (k = 2), it was impossible to assess perform Egger's test or funnel plot. Subgroup and sensitivity analysis was deemed inappropriate given the small number of studies and the low heterogeneity ($I^2 = 0.0\%$).

Diastolic blood pressure

The random-effects model was utilized to synthesize the MD across ten studies, considering the variability within and between studies. The analysis included 2,269 observations, with 1,127 in the experimental group and 1,142 in the control group. The pooled effect size under the random-effects model was −2.66 (95% CI: −4.63 to −0.70, $I^2 = 85\%$, $p<0.01$), indicating a statistically significant reduction in DBP in the experimental group compared to the control group. The prediction interval ranged from −9.59 to 4.26, reflecting the potential variability in true effect sizes across different settings (Fig. 3).

Publication bias

The funnel plot appeared asymmetric, suggesting potential publication bias or other small-study effects. To further investigate, Egger's test for funnel plot asymmetry was conducted. The test result was not significant (t = −0.34, df = 8, $p=0.74$), indicating no evidence of publication bias according to this test. The discrepancies between the funnel plot and Egger's test results might be explained by factors other than publication bias, such as true heterogeneity or differences in study quality (Fig. 4).

Subgroup and sensitivity analysis

Subgroup analyses were performed to explore potential sources of heterogeneity. Significant variability in the effectiveness of interventions was observed across different subgroups. The difference was insignificant for the "Risk of Bias" ($p=0.77$) effect. Country-wise, effect sizes varied widely, with Australia showing a substantial reduction in effect size (MD −2.31) and significant between-group differences ($p<0.01$). Similarly, the SMS type and frequency demonstrated variability, with significant differences in effect sizes between subgroups ($p<0.01$), being the two messages per week (MD −7.05) and reminder type of message (MD −6.68) subgroups. Such subgroups showed a major effect. Notably, the source of the message (automated system versus nurse-led) also influenced the results ($p<0.01$), with nurse-led interventions showing a more substantial effect (MD −7.05). Sensitivity analyses, including leave-one-out analysis, did not identify any specific study influencing the overall results, showing the robustness of the findings (Supplementary Tables 7–8).

Systolic blood pressure

The random-effects model was utilized to synthesize the MD across eleven studies, considering the variability within and between studies. The analysis included 3,183 observations, with 1,584 in the experimental group and 1,599 in the control group. The pooled effect size under the random-effects model was −6.12 (95% CI: −10.26 to −1.97, $I^2 = 96\%$, $p<0.01$), indicating a statistically significant reduction in SBP in the experimental group compared to the control group. The prediction interval ranged from −21.77 to 9.54, reflecting the potential variability in true effect sizes across different settings (Fig. 3).

Publication bias

The funnel plot appeared asymmetric, suggesting potential publication bias or other small-study effects. To further investigate, Egger's test for funnel plot asymmetry was conducted. The test result was not significant (t = −1.08, df = 9, $p=0.31$), indicating no evidence of publication bias according to this test. The discrepancies between the funnel plot and Egger's test results might be explained by factors other than publication bias, such as true heterogeneity or differences in study quality (Fig. 4).

Subgroup and sensitivity analysis

Subgroup analyses were performed to explore potential sources of heterogeneity. Significant variability in the effectiveness of interventions was observed across different subgroups. The country subgroup analysis revealed substantial negative effect sizes with a marked reduction effect size on Russia (MD −21.60), with significant between-group differences ($p<0.01$). Additionally, the frequency of the SMS subgroup showed notable effect sizes for "Daily" (MD −21.60), with significant differences ($p<0.01$). The source of the message also influenced

Fig. 2 Risk of bias. Traffic light Plot showing twelve articles (55%) indicated some concerns, while the remaining ten articles (45%) demonstrated a low risk of bias

the results, with nurse-led interventions (MD −13.16) showing a significant effect ($p<0.01$). The reminders and education type of messages showed a reduction in SBP (MD −12.04) with significant effect differences between groups ($p<0.01$). Sensitivity analyses, including leave-one-out analysis, identified Kiselev A, [33] influencing the overall outcomes. The pooled effect size after excluding this study remained robust, with a MD −4.49 (95% CI: −7.42 to −1.55, $p=0.002$, I^2 = 87.4%) (Supplementary Tables 9–10).

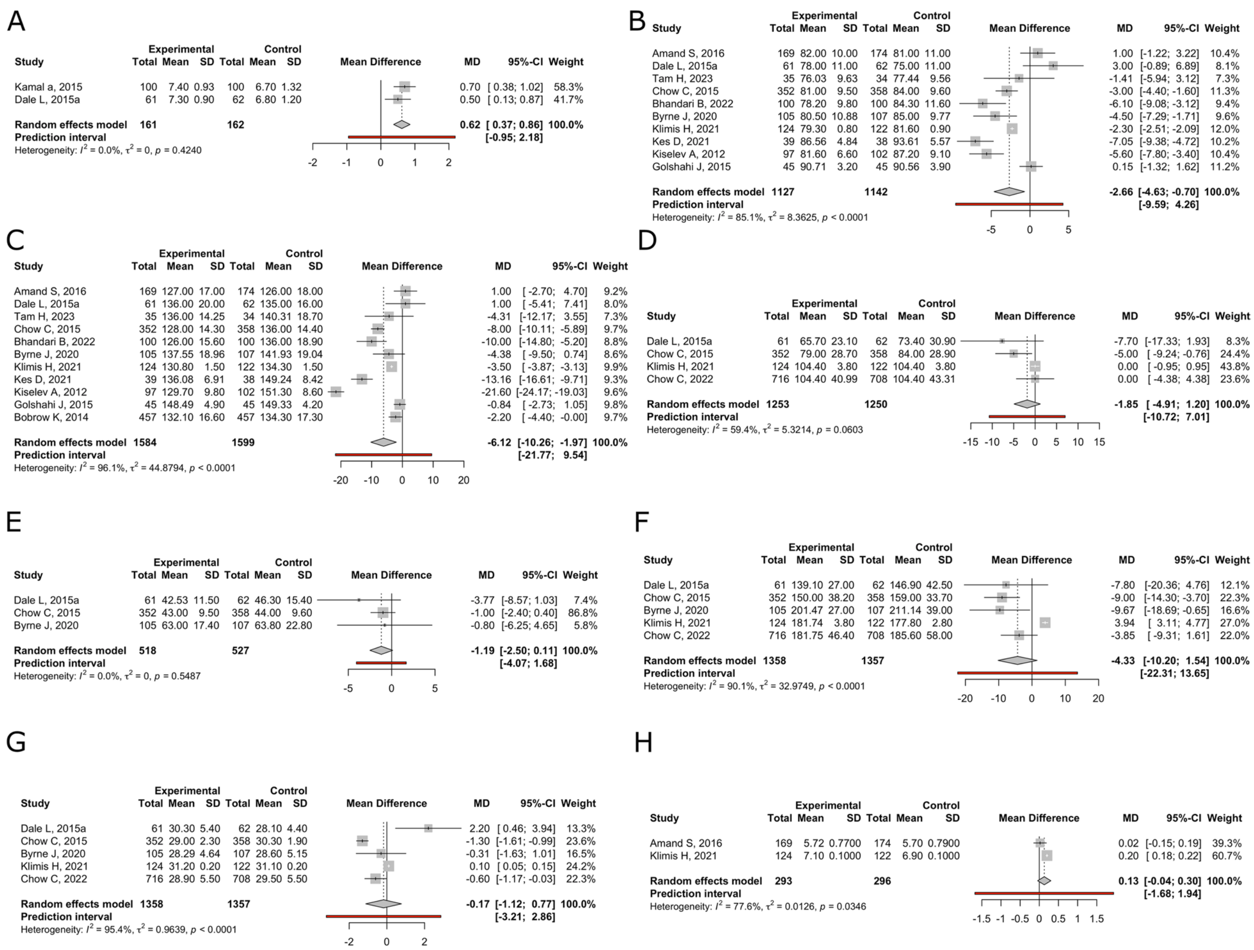

Fig. 3 Meta-analysis forest plots. Forest plot of studies showing 95% CI and overall effect size for: **A** Medication adherence (Morisky score), **B** Diastolic blood pressure , **C** Systolic blood pressure , **D** LDL levels, **E** HDL levels, **F** Total cholesterol, **G** BMI, and (**H**) HbA1c

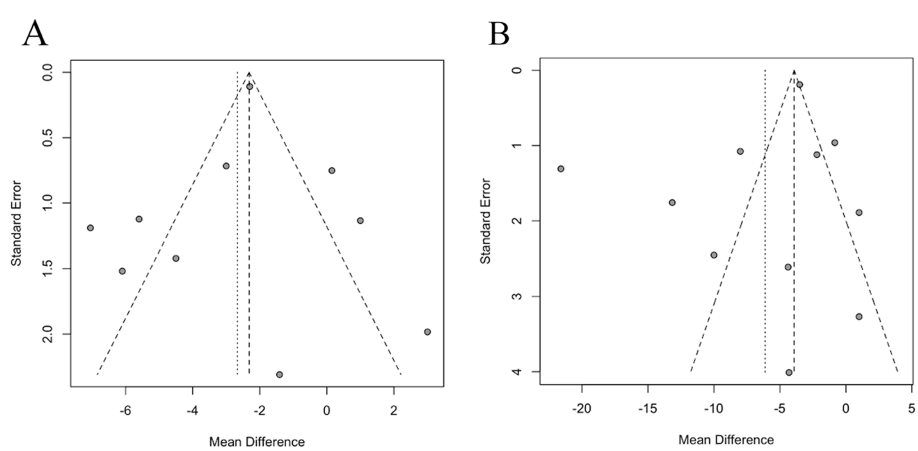

Fig. 4 Funnel plots for publication bias. Funnel plot analysis for assessing publication bias in: **A** Diastolic blood pressure , **B** Systolic blood pressure

LDL

The random-effects model was utilized to synthesize the MD across four studies, considering the variability within and between studies. The analysis included 2,503 observations, with 1,253 in the experimental group and 1,250 in the control group. The pooled effect size under the random-effects model was −1.85 (95% CI: −4.91 to 1.20, I^2 = 59.4%, $p = 0.23$), indicating no statistically significant reduction in the outcome of interest in the experimental group compared to the control group. The prediction interval ranged from −10.72 to 7.01, reflecting the potential variability in true effect sizes across different settings (Fig. 3). Due to the limited number of studies (k = 4), it was not possible to assess publication bias using Egger's test or funnel plot.

Subgroup and sensitivity analysis

Subgroup analyses revealed that only the "Type of SMS" subgroup had a significant effect on "Lifestyle text messages" with an MD effect size of −5.00 (95% CI: −9.23 to −0.76). Other subgroups, including "Risk of Bias," "Country," "Type of Transmission," "Frequency of SMS," and "Who Sends the Message," did not show significant effects, indicating no substantial differences within these categories. Sensitivity analyses, including leave-one-out analysis, identified Chow C, 2015 [21], Klimis H, [12], and Chow C, [28] as outliers. A previous analysis without the identified studies was not possible due to the lower number of remaining studies (Supplementary Tables 11–12).

HDL

The random-effects model was utilized to synthesize the MD across three studies, considering the variability within and between studies. The analysis included 1,045 observations, with 518 in the experimental group and 527 in the control group. The pooled effect size under the random-effects model was −1.19 (95% CI: −2.50 to 0.11, I^2 = 0.0%, $p = 0.07$). The prediction interval ranged from −4.07 to 1.68, reflecting the potential variability in true effect sizes across different settings (Fig. 3). Due to the limited number of studies (k = 3), it was impossible to assess perform Egger's test or funnel plot. Subgroup and sensitivity analysis was deemed inappropriate given the small number of studies and the low heterogeneity (I^2 = 0.0%).

Total cholesterol

The random-effects model was utilized to synthesize the MD across five studies, considering the variability within and between studies. The analysis included 2,715 observations, with 1,358 in the experimental group and 1,357 in the control group. The pooled effect size under the random-effects model was −4.33 (95% CI: −10.20 to 1.54, I^2 = 90%, $p = 0.14$). The prediction interval ranged from −22.31 to 13.65, reflecting the potential variability in true effect sizes across different settings (Fig. 3). Due to the limited number of studies (k = 5), it was not possible to conduct Egger's test and funnel plot to further assess publication bias.

Subgroup and sensitivity analysis

The subgroup analysis, including ''Type of SMS," "Risk of Bias," "Country," "Type of Transmission," "Frequency of SMS," and "Who Sends the Message," did not show significant effects, indicating no substantial differences within these categories. Sensitivity analyses, including leave-one-out analysis, identified Klimis H, 2021, as an influential study. Excluding this study led to a revised analysis with four remaining studies involving 2,469 observations (1,234 in the experimental group and 1,235 in the control group). The pooled effect size under the random-effects model was MD −7.06 (95% CI: −10.61 to −3.51, I^2 = 0%, $p < 0.01$), indicating a statistically significant reduction in total cholesterol in the experimental group compared to the control group (Supplementary Tables 13–14).

BMI

The random-effects model was utilized to synthesize the SMD across five studies, considering the variability within and between studies. The analysis included 2,715 observations, with 1,358 in the experimental group and 1,357 in the control group. The pooled effect size under the random-effects model was MD −0.17 (95% CI: −1.12 to 0.77, I^2 = 95%, $p = 0.71$). The prediction interval ranged from −3.21 to 2.86, reflecting the potential variability in true effect sizes across different settings (Fig. 3). Due to the limited number of studies (k = 5), it was not possible to conduct Egger's test and funnel plot to further assess publication bias.

Subgroup and sensitivity analysis

Subgroup analyses revealed mixed outcomes. For the "Risk of Bias" subgroup, the effect size for studies with some risk of bias was MD 2.20, indicating an increase and significant effect, significantly different between groups ($p = 0.004$). Similarly, in the "Country" subgroup, studies from New Zealand had an increase and significant effect size. For the "Type of SMS" subgroup, "Comprehensive cardiac rehab" showed an increase and significant effect size of MD 2.20, while "Lifestyle text messages" showed a significant reduction effect size of MD −1.30. None of the frequency categories or sender subgroups showed a statistically significant difference. Sensitivity analyses, including leave-one-out analysis, identified Chow C, 2015

[21], as an influential study. Excluding this study led to a revised analysis with four remaining studies involving 2,005 observations (1,006 in the experimental group and 999 in the control group). The pooled effect size under the random-effects model was MD 0.17 (95% CI: −0.14 to 0.49, I^2 = 88.2%, $p = 0.28$), indicating no significant change in BMI. The test of heterogeneity was significant (Q (3) = 25.34, $p < 0.01$), suggesting substantial variability between the study results even after excluding the influential study (Supplementary Tables 15–16).

HbA1c

The random-effects model was utilized to synthesize the SMD across two studies, considering the variability within and between studies. The analysis included 589 observations, with 293 in the experimental group and 296 in the control group. The pooled effect size under the random-effects model was MD 0.13 (95% CI: −0.04 to 0.30, $I^2 = 78\%$, $p = 0.14$). The prediction interval ranged from −1.68 to 1.94, reflecting the potential variability in true effect sizes across different settings (Fig. 3). Due to the limited number of studies (k = 2), it was not possible to conduct Egger's test and funnel plot to further assess publication. Subgroup and sensitivity analyses were not performed due to the small number of studies, despite the high heterogeneity ($I^2 = 99.1\%$).

Discussion

In light of the growing interest in digital interventions, which offer easy access and cost-effective solutions for health promotion, our systematic review and meta-analysis, synthesizing data from 22 articles, aimed to measure the efficacy of text messaging as a tool for CVD risk factor control. As digital interventions become increasingly prevalent, they provide a promising approach to delivering health behavior change at a low cost and with broad reach. By focusing on outcomes such as smoking cessation, HbA1c levels, SBP, DBP, cholesterol levels, and medication adherence, we sought to address the gap in the literature concerning the impact of text messaging on CVD risk factors.

While the selected publications had varied results, our systematic analysis showed a positive effect on cardiovascular risk factor control using text messaging interventions compared to no intervention. Of the selected publications, 61% demonstrated a positive effect on cardiovascular risk factor control using text messaging interventions, while the remaining 39% showed no significant difference. Most of the selected articles in our review demonstrated a low risk of bias, with 55% of studies meeting this criterion and 45% exhibiting some concerns regarding the risk of bias. The clinical inference drawn from these research findings suggests that integrating text messaging interventions into cardiovascular risk factor control and management could offer tangible benefits for patients. With most publications demonstrating a positive effect, healthcare providers may consider incorporating such interventions to complement existing treatments. However, it is essential for clinicians to critically evaluate the quality of evidence, considering the risk of bias in some studies. Therefore, while integrating text messaging could enhance cardiovascular risk factor control strategies, clinicians should exercise caution when applying these findings and remain vigilant for emerging evidence to ensure the interventions are used effectively and appropriately.

The findings from our analysis highlight the significant impact of text messaging interventions on various cardiovascular risk factor control outcomes. Firstly, the random-effects model revealed a substantial and statistically significant reduction in SBP, with an MD of −6.12 (95% CI: −10.26 to −1.97, $p < 0.01$, I^2 = 96%). This indicates that text messaging interventions are effective in lowering SBP. Additionally, the analysis of ten studies related to DBP revealed an MD pooled effect size of −2.66 (95% CI: −4.63 to −0.70, $p < 0.01$, I^2 = 85%), signifying a significant reduction in DBP due to text messaging interventions. However, the high heterogeneity indicates variability in the effect across different studies, highlighting the need to consider context and individual study characteristics carefully. For example, the subgroups for SBP and DBP showed that frequent text messages, reminders, educational messages, and nurse-led messages had a more significant impact on reducing these variables. It is important to note that the risk of CVD increases steadily with progressively higher levels of baseline SBP and DBP, above a usual SBP and DBP of 115 and 75 mmHg, respectively [36]. According to the guidelines outlined in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [37], managing both SBP and DBP is essential for decreasing the likelihood of cardiovascular events. The report underscores the importance of integrating text messages into CVD risk factor control by addressing DBP to reduce the occurrence of cardiovascular diseases such as coronary artery disease, heart failure, stroke, and peripheral vascular disease. In comparison to our study, a meta-analysis of six studies [10] reported a significant reduction in DBP, with an MD of −6.11 mmHg ($p < 0.01$) with text messaging intervention, aligning with our findings. This study also found no significant reduction in SBP with text messaging, contrasting with our results, where we found a statistically significant result. This difference can be attributed to the smaller sample size in the aforementioned study and the larger sample size and broader range of studies in our analysis. The variability in DBP outcomes across studies, reflected in the high heterogeneity, underscores the need for context-specific considerations when interpreting these results, as DBP reduction could be clinically insignificant, while SBP reduction may be considerable. These results are important when compared with other interventions, such as the Dietary Approaches to Stop Hypertension (DASH) diet or sodium intake reduction, which, according to previous guidelines such as those from the American Heart Association [38, 39] can reduce SBP by 11 mmHg and 5–6 mmHg, respectively. This makes text messaging a powerful tool to help manage SBP as a cardiovascular risk factor.

Regarding medication adherence, we demonstrated an MD pooled effect size of 0.62 (95% CI: 0.37 to 0.86; $p < 0.01$, I^2 = 0.0%). This significant positive effect indicates that text messaging interventions notably improve medication adherence, as measured by the Morisky score, but this effect was based only in two studies limiting the generabilizity of the results. The low heterogeneity suggests that the impact on medication adherence is relatively consistent across the included studies. This finding is consistent with a previous study that reported a moderate effect size (SMD = 0.65, $p = 0.01$) in older adults with hypertension, suggesting that text messaging effectively improves adherence across different populations. However, in our analysis, we demonstrated that this effect is maintained with an I^2 = 0%, unlike the previous analysis, which showed an I^2 = 85%, raising concerns about its reliability [10]. This reveals that while text messaging interventions generally show positive effects on SBP, DBP, and medication adherence, the magnitude and consistency of these effects can vary. This variability can be attributed to several factors, as demonstrated in our subgroup analysis, where differences were observed based on the content of the message, the timing of the message, and the sender of the message. The variability in outcomes across studies emphasizes the need for personalized interventions tailored to specific populations and settings, and it calls for further research to refine and validate this digital tool for more consistent and effective results.

The findings from our meta-analysis indicate no significant improvement in BMI, LDL, HDL, total cholesterol, or HbA1c levels due to text messaging interventions, for tis results the analysis of HbA1c was based on two studies limiting the generabilization of the results. This contrasts with some previous research reporting significant changes in these metrics. For instance, a previously reported meta-analysis [40] found that text messaging interventions had a positive impact on HbA1c levels, resulting in significant reductions with an MD of −0.38 (95% CI: −0.53 to −0.23, $p < 0.001$). Another meta-analysis [41] reported significant improvements in cholesterol levels (SMD = −0.26; 95% CI: −0.40 to −0.12, $p < 0.01$). Despite our initial analysis revealing no significant reduction, sensitivity analysis excluding Klimis H, 2021, as an influential study demonstrated a similar effect, with an MD of −7.06 (95% CI: −10.61 to −3.51, I^2 = 0%, $p < 0.0001$). Another meta-analysis [42] observed a moderate and statistically significant effect on BMI reduction (−0.43 kg/m^2; 95% CI: −0.63 to −0.23, I^2 = 62%, $p = 0.001$). This effect could be attributed to the inclusion of studies utilizing mobile health interventions beyond text messages. Conversely, another meta-analysis [43] focused solely on text messages found no statistically significant reduction in BMI (SMD = −3.61; 95% CI: −9.48 to 2.26, $p = 0.23$). Additionally, this study found changes in HDL and LDL levels to be statistically non-significant: LDL (SMD = −1.81; 95% CI: −4.80 to 1.18, $p = 0.24$) and HDL (SMD = −1.15; 95% CI: −2.83 to 0.54, $p = 0.18$). These findings suggest that while text messaging interventions can improve certain cardiovascular outcomes, such as blood pressure and medication adherence, their effects on weight management, HbA1c, and lipid profiles might be less pronounced. In general, our analysis is consistent with previous findings for LDL, HDL, and cholesterol levels but contrasts with findings for HbA1c and BMI. This discrepancy could be due to differences in the included studies, as our meta-analysis exclusively focused on text message interventions rather than a broader range of mobile health interventions, offering a purer assessment of text messaging alone on these variables. Other studies have shown significant reductions in weight, BMI, waist circumference, and HbA1c levels due to text messaging interventions, though changes in lipid levels were not consistently significant. These discrepancies emphasize the need for tailored digital interventions for individual risk profiles and study-specific contexts. Future research should aim to integrate a comprehensive set of outcome measures to better evaluate the impact of text messaging interventions on cardiovascular risk factor control.

Our analysis demonstrated that text messaging interventions significantly reduced SBP and DBP, crucial cardiovascular health indicators. In addition to improving blood pressure, our study found a significant positive effect on medication adherence. This suggests that text messaging interventions notably enhance adherence to prescribed medication regimens, aligning with previous research highlighting the role of digital tools in improving patient compliance. Our results indicate that text messaging interventions can improve CVD risk factors. For this reason, physicians should consider incorporating text messaging into patient management and customizing messages to meet individual needs and health goals.

This approach offers continuous support, helps patients stay engaged, and allows for progress monitoring and timely treatment adjustments. However, physicians must critically assess the evidence, accounting for variability and potential biases. Despite previous works on the use of text messaging to improve cardiovascular risk factors, our study addresses a broader range of outcomes. Unlike earlier meta-analyses that focused on a limited set of outcomes, we include additional measures such as smoking cessation, medication adherence, and levels of LDL and HDL, providing a more comprehensive evaluation. By incorporating a quantitative meta-analysis, this study offers an updated understanding of the effectiveness of text messaging interventions in managing cardiovascular disease (CVD) risk factors [44].

Limitations and future research

The substantial heterogeneity in several results indicates considerable variability between studies. Although subgroup analyses were performed to identify sources of variability, the persistent heterogeneity raised concerns regarding the comparability of the studies, limited the reliability of pooled estimates, and warrants cautious interpretation. Additionally, the methodological quality of four included studies raised concerns about the risk of bias in the randomization process. In comparison, twelve studies had some concerns about selecting the reported results. Another limitation was the lack of detailed information regarding the medications that patients were taking, as this was not reported in the pooled studies. Furthermore, the limited number of studies made performing subgroup and sensitivity analyses on some parameters impossible, precluding reliable subgroup differentiation and sensitivity assessment. The sample sizes of some RCTs included were also small, with seven studies having 100 or fewer participants. The inconsistency and lack of standardization in outcome measurement protocols, particularly for blood pressure, limited the reliability of our findings. Variations in device types, measurement frequency, and timing were often unclear or inconsistently reported, affecting comparability across studies.

The limited number of studies underscores the need for additional research to validate our findings, explore potential moderators of intervention effectiveness, and address methodological challenges. For example, smoking, as a significant CVD risk factor, showed outcomes in only four studies with no clear number to perform the analysis. Future research should aim to evaluate more interventions using nurse-led text messages and obtain additional information on lifestyle changes, including physical activity, smoking cessation, healthier diets, BMI reduction, and patient medications. Moreover, no studies assessed the effects of text messaging beyond the 12-month follow-up. Future research should address specific gaps, such as optimizing message frequency to improve adherence and lifestyle changes, tailoring interventions for specific subpopulations to enhance effectiveness, and reporting interactions between SMS interventions and medications. Additionally, factors influencing efficacy, such as cultural, psychological, or healthcare system differences, should be explored. Addressing these areas will refine SMS-based interventions, enhance their impact, and support scalability for global cardiovascular disease prevention.

Conclusion

This systematic review and meta-analysis demonstrate that text messaging interventions can significantly improve cardiovascular risk factor control by enhancing medication adherence and reducing systolic and diastolic blood pressure, both critical for cardiovascular health. These findings highlight the potential of text messaging as an effective tool in CVD prevention. Despite these positive outcomes, the high heterogeneity observed in blood pressure measures and the lack of significant effects on other cardiovascular risk factors, such as BMI, LDL, HDL, total cholesterol, and HbA1c, underscore the variability in intervention effectiveness across different settings and populations. This suggests that while text messaging can enhance certain health behaviors, its impact on broader cardiovascular risk factor control metrics may be limited. Nevertheless, integrating text messaging interventions into existing healthcare strategies offers a promising and cost-effective approach to improving medication adherence and blood pressure control, both vital for preventing cardiovascular events. Future research should focus on long-term effects, comprehensive lifestyle changes, and tailoring interventions to enhance their efficacy across diverse populations. Addressing these gaps will be crucial for refining digital health technologies and optimizing their role in CVD prevention.

Abbreviations

CVDs	Cardiovascular Diseases
PRISMA	Preferred Reporting Items for Systematic Review and Meta-Analysis
RCTs	Randomized Clinical Trials
DBP	Diastolic Blood Pressure
SBP	Systolic Blood Pressure
BMI	Body Mass Index
LDL	Low-Density Lipoprotein
HDL	High-Density Lipoprotein
HbA1c	Hemoglobin A1c
MeSH	Medical Subject Headings
CI	Confidence Interval
SMD	Standardized Mean Difference
k	Number of Studies

Supplementary Information

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Supplementary Material 1.

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Data availability
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
This study did not require ethical approval in accordance with local guidelines, as it is a meta-analysis of previously published data. No new individual patient data were collected or analyzed; therefore, patient consent was not necessary for this research. All data utilized in this analysis were sourced from studies that had obtained the requisite ethical approvals and informed consent from participants.

Consent for publication
The authors consent for publication of all tables, figures and contents that were generated through author's original analysis of data included in meta-analysis.

Competing interests
The authors declare no competing interests.

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