



Systematic Review

Digital health interventions for chronic disease prevention and management in Saudi Arabian populations: A systematic review

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Received: 30 November 2025

Accepted: 12 January 2026

Published: 01 March 2026

DOI

10.25259/IJHS_372_2025

Quick Response Code:



Supplementary materials are
available at:

[https://dx.doi.org/10.25259/
IJHS_372_2025](https://dx.doi.org/10.25259/IJHS_372_2025)

ABSTRACT

Objectives: Saudi Arabia faces substantial chronic disease burden, with diabetes affecting ~7 million citizens and cardiovascular diseases, accounting for 37% of deaths. Vision 2030 prioritizes digital health solutions for the prevention and management of health issues. This systematic review evaluated digital health interventions for chronic disease prevention and management in Saudi Arabia.

Methods: Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines (PROSPERO CRD420251107628), we searched MEDLINE, PubMed, Embase, and CENTRAL (January 2010–July 2025) for studies evaluating digital health interventions (mobile apps, telehealth, wearables, AI tools, SMS, and remote monitoring) in Saudi adults. Two reviewers independently assessed quality using Cochrane risk of bias-2 (RoB), RoB in non-randomized studies of interventions, and mixed methods appraisal tool. Meta-analysis used RevMan 5.4 with random-effects models. Grading of recommendations assessment, development, and evaluation evaluated evidence certainty.

Results: Thirteen studies (3783 participants) met the inclusion criteria. SMS programs reduced hemoglobin A1C (HbA1c) from $9.9 \pm 1.8\%$ to $9.5 \pm 1.7\%$; mobile systems enhanced glycemic control. Sehhaty platform reached >24 million users. Meta-analysis showed moderate-certainty evidence for HbA1c improvement (MD -0.49% , 95% confidence interval [CI]: -0.76 to -0.22) and medication adherence (odds ratio 2.34, 95% CI: 1.67–3.28), but low-certainty evidence for blood pressure control. Challenges included technical barriers (45.6% of cardiovascular patients) and lower rural adoption.

Conclusion: Moderate-certainty evidence supports digital health interventions – particularly mobile apps and SMS – for chronic disease management in Saudi Arabia. However, evidence for blood pressure control and long-term engagement remains of low certainty. Implementation requires cultural adaptation, healthcare system integration, and addressing barriers in elderly and rural populations. Future research should assess long-term effectiveness, cost-effectiveness, and tailored implementation strategies.

Keywords: Cardiovascular disease, Chronic disease management, Chronic disease prevention, Diabetes, Digital health, Mobile health, Saudi Arabia, Systematic review, Telemedicine

How to cite this article: Almohammadi A, Alsobhi S, Almohammadi H. Digital health interventions for chronic disease prevention and management in Saudi Arabian populations: A systematic review. Int J Health Sci (Qassim). 2026;20:111-23. doi: 10.25259/IJHS_372_2025

INTRODUCTION

Saudi Arabia is facing a growing epidemic of chronic diseases that poses significant risks to public health and jeopardizes the objectives outlined in the nation's Vision 2030 healthcare transformation initiative. Approximately 7 million individuals in Saudi Arabia are affected by diabetes, placing the Kingdom as the second highest in the Middle East and seventh globally regarding diabetes prevalence.^[1] Cardiovascular diseases are responsible for 37% of all deaths, establishing them as the leading cause of mortality from non-communicable diseases.^[2] As of 2023, obesity rates have soared to 21.4%, with associated economic impacts estimated at \$6.4 billion annually.^[3] This burden of chronic disease illustrates Saudi Arabia's swift epidemiological shift from communicable to non-communicable diseases, a transition fueled by lifestyle changes, urbanization, and demographic evolution.

Globally, digital health interventions have demonstrated effectiveness in chronic disease management. Meta-analyses show hemoglobin A1C (HbA1c) reductions of 0.25–0.49% with mobile health applications for diabetes,^[4–6] while systematic reviews of cardiovascular interventions demonstrate improved medication adherence.^[7,8] Text messaging interventions combined with diabetes self-management education show HbA1c reductions of approximately 0.3–0.4%.^[9]

The Vision 2030 healthcare transformation framework explicitly identifies digital health solutions as essential components for achieving comprehensive and integrated healthcare delivery.^[10] The National E-Health Strategy, launched in 2011, aims to establish unified electronic health records for all citizens, while the Health Sector Transformation Program endeavors to reconfigure healthcare into a digitally supported system.^[11,12] Digital health investments in Saudi Arabia have the potential to yield substantial economic benefits through improved healthcare delivery and reduced utilization of emergency services.^[11,12]

Digital health interventions hold particular promise within Saudi Arabia's distinctive cultural and geographic landscape. With high internet penetration and a sophisticated telecommunications framework, the Kingdom is well-equipped for deploying digital health solutions.^[13] Cultural factors such as strong familial involvement in healthcare decisions and preference for Arabic language interfaces present both opportunities and challenges for the design of these interventions.^[14,15] Previous initiatives in digital health, such as the Sehhaty platform that serves over 24 million users, demonstrate substantial governmental commitment as well as population acceptance.^[14,15]

Despite the rising implementation of digital health technologies, there remains a lack of systematic evidence

evaluating their effectiveness in preventing chronic diseases and supporting disease management to prevent complications among populations in Saudi Arabia. Current literature predominantly addresses general outcomes related to digital health or focuses on individual types of interventions without providing a thorough evaluation of effectiveness across diverse populations and healthcare settings within Saudi Arabia. Notable gaps exist regarding culturally tailored interventions, long-term clinical efficacy, and implementation variables specific to Saudi Arabian healthcare systems.

This systematic review aims to bridge these knowledge deficits by conducting a comprehensive assessment of digital health interventions aimed at preventing chronic diseases and supporting the management of existing conditions to prevent complications within Saudi Arabian populations. Our primary goal is to systematically evaluate the effectiveness of mobile applications, telehealth platforms, wearable devices, AI-driven tools, web-based programs, text messaging initiatives, and remote monitoring systems targeting diabetes prevention, cardiovascular disease management, and obesity reduction. Secondary objectives focus on assessing clinical outcomes, examining changes in health behaviors, exploring implementation factors, and identifying optimal characteristics for interventions tailored specifically to the context of Saudi Arabia.

MATERIALS & METHODS

Protocol and registration

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and registered prospectively with PROSPERO (registration number: CRD420251107628). The review protocol was developed a priori and followed throughout the review process.

Eligibility criteria

Inclusion criteria

Studies were included if they involved adults aged 18 years and older residing in Saudi Arabia who were at risk for chronic diseases (diabetes, cardiovascular disease, and obesity) or had been diagnosed with these conditions. Eligible interventions included digital health technologies such as mobile health applications, telehealth and telemedicine platforms, wearable devices and sensors, AI-powered diagnostic or management tools, web-based educational or management programs, text messaging (SMS) interventions, and remote monitoring systems. Studies could compare interventions against standard care, waitlist controls, alternative interventions, or use pre-post comparisons for single-arm studies. Primary

outcomes of interest included clinical measures (HbA1c, blood pressure, body mass index, and lipid profiles) and health behaviors (physical activity, dietary adherence, and medication compliance), while secondary outcomes encompassed user engagement metrics, implementation feasibility, and cost-effectiveness measures.

Eligible study designs included randomized controlled trials, cluster randomized trials, quasi-experimental studies, controlled before-and-after studies, interrupted time series, prospective cohort studies, cross-sectional studies with intervention evaluation, and pilot or feasibility studies. Only primary research studies were included; systematic reviews, meta-analyses, editorials, commentaries, and conference abstracts without full-text availability were excluded. Publications were limited to English and Arabic languages from January 2010 to July 2025.

The search timeframe of January 2010–July 2025 was selected to capture the evolution of digital health interventions in Saudi Arabia following the launch of the National E-Health Strategy in 2011 and the subsequent expansion of smartphone penetration and digital infrastructure in the Kingdom over the past decade.

Exclusion criteria

Studies conducted exclusively in populations outside Saudi Arabia; children and adolescents under 18 years of age; studies focusing solely on acute care or emergency interventions rather than chronic disease prevention or management; digital tools used only for administrative purposes (scheduling and billing) without direct health intervention; and conference abstracts, case reports, editorials, or commentaries without full-text availability.

For studies involving multiple countries, we included only those where Saudi Arabian data were reported separately or where the Saudi Arabian sample comprised $\geq 50\%$ of the total study population, allowing for meaningful interpretation of findings relevant to the Saudi context. Cross-sectional studies were included only when they evaluated specific digital health interventions with measurable outcomes, not those solely assessing prevalence or attitudes without intervention assessment.

Search strategy

We conducted comprehensive searches of MEDLINE (through PubMed), Embase, Cochrane Central Register of Controlled Trials (CENTRAL), and gray literature sources from January 2010 to July 2025. Search strategies combined controlled vocabulary terms (MeSH, Emtree) and free-text keywords related to digital health interventions, chronic diseases, and Saudi Arabian populations. A representative search string for MEDLINE was: (“Digital Health” [MeSH]

OR “digital health” OR “eHealth” OR “mHealth” OR “mobile health” OR “telemedicine” OR “telehealth” OR “wearable*” OR “artificial intelligence” OR “text message*” OR “SMS” OR “web-based”) AND (“Saudi Arabia” [MeSH] OR “Saudi Arabia” OR “Kingdom of Saudi Arabia”) AND (“Diabetes Mellitus” [MeSH] OR “diabetes” OR “Cardiovascular Diseases” [MeSH] OR “cardiovascular” OR “hypertension” OR “Obesity” [MeSH] OR “obesity” OR “Chronic Disease” [MeSH] OR “chronic disease*”). Language restrictions included English and Arabic publications. Complete search strategies for all databases are provided in Table S1. Gray literature searches targeted Saudi Ministry of Health reports, university repositories (King Saud University, King Abdulaziz University, Prince Mohammad Bin Salman University), and conference proceedings. Backward and forward citation tracking was not performed.

Study selection and data extraction

Two reviewers independently screened titles, abstracts, and full-text articles using predetermined inclusion and exclusion criteria. Inter-rater agreement for study selection was substantial (Cohen’s kappa = 0.82). Disagreements were resolved through discussion or consultation with a third reviewer. Data extraction utilized standardized forms that were piloted on three studies to ensure clarity and completeness before full data extraction. The forms captured study characteristics, participant demographics, intervention details, outcome measures, and results. Authors of included studies were not contacted for missing or unclear data, as specified in the registered protocol.

Of the 13 included studies, none were published exclusively in Arabic-language journals. All identified relevant Arabic-language publications were also available in English versions. For studies with Arabic-language supplementary materials, two bilingual researchers independently translated and verified the content to ensure accuracy in data extraction.

Quality assessment

The quality of studies was evaluated using validated tools suitable for their design. The Cochrane risk of bias tool (RoB-2) was used for randomized trials, the RoB in non-randomized studies of interventions for non-randomized studies, and the mixed methods appraisal tool (MMAT) for cross-sectional, quasi-experimental, and pilot studies. The MMAT was selected because it is specifically designed to evaluate diverse study designs with standardized criteria, facilitating consistent quality assessment across the range of methodologies included in this review.

Each study was independently assessed by two reviewers using the appropriate quality assessment criteria. Overall

RoB ratings (low risk, some concerns, and high risk) were assigned according to the tool-specific guidance: Studies with no serious concerns in any domain were rated as low risk, those with concerns in one domain as some concerns, and those with serious concerns in multiple domains as high risk. Inter-rater agreement for quality assessment was good (Cohen's kappa = 0.76). All disagreements were resolved through discussion between the two reviewers, and when consensus could not be reached, a third reviewer was consulted.

Common bias patterns across studies included: (1) lack of blinding for subjective outcomes in 8 of 13 studies (62%), particularly for self-reported behavioral outcomes; (2) selection bias in cross-sectional studies using convenience sampling (5 of 13 studies, 38%); (3) high attrition rates (>20%) in technology-based interventions in 4 of 13 studies (31%); and (4) inadequate randomization procedures in non-randomized controlled trial (RCT) designs (6 of 13 studies, 46%).

Data synthesis

Due to substantial heterogeneity in intervention types, study designs, and outcome measures, meta-analysis was not feasible for most outcomes. We conducted narrative synthesis using structured tabulation of study characteristics, thematic grouping by intervention type (mobile applications, telehealth, text messaging, and wearables), and examination of clinical outcomes, behavioral changes, and implementation factors.

Where sufficient homogeneity existed (HbA1c outcomes from mobile app and SMS interventions, and medication adherence outcomes), we conducted random-effects meta-analysis using the DerSimonian-Laird method in RevMan 5.4 (Cochrane Collaboration). For HbA1c outcomes, all five studies reported mean differences and standard deviations at similar time points (4–8 months), used comparable measurement methods (laboratory HbA1c assays), and targeted similar populations (adults with type 2 diabetes or prediabetes). For medication adherence, studies reporting dichotomous outcomes (adherent vs. non-adherent) were pooled. Studies with multiple intervention arms were analyzed by combining intervention groups when appropriate or by splitting the control group to avoid double-counting, following Cochrane Handbook guidance. Statistical heterogeneity was assessed using I^2 statistics, with $I^2 < 40\%$ considered low heterogeneity, 40–60% moderate, and >60% substantial heterogeneity.

Publication bias assessment through funnel plots was not feasible due to the limited number of studies ($n = 5$ for HbA1c; $n = 5$ for medication adherence), as a minimum of 10 studies is generally recommended for meaningful interpretation of funnel plot asymmetry.

Findings were organized by technology type and chronic disease focus, with attention to Saudi Arabian contextual factors. Grading of recommendations assessment, development, and evaluation (GRADE) methodology assessed certainty of evidence for primary outcomes. Two reviewers independently conducted GRADE assessments, with disagreements resolved through discussion. GRADE assessments considered five domains: RoB, inconsistency, indirectness, imprecision, and publication bias. Evidence was rated as high, moderate, low, or very low certainty based on these criteria.

RESULTS

Study selection

The search strategy identified 6,847 titles across all databases. After removing 1,923 duplicates, 4,924 titles and abstracts were screened. Full-text review was conducted for 67 potentially eligible studies. After removing one study that included pediatric participants inconsistent with our eligibility criteria, 13 studies ultimately met inclusion criteria and were included in the final analysis. The PRISMA flow diagram is presented in Figure 1.

Study characteristics

The 13 included studies encompassed 3,783 participants across multiple Saudi regions, with the majority conducted in Riyadh ($n = 7$) and Jeddah ($n = 3$). Study designs included three randomized controlled trials, five quasi-experimental studies, three cross-sectional intervention evaluations, and two pilot feasibility studies. Intervention types were distributed as follows: mobile health applications ($n = 6$, 46.2%), text messaging interventions ($n = 3$, 23.1%), telehealth platforms ($n = 3$, 23.1%), and wearable devices ($n = 1$, 7.7%). Note that percentages total >100% as some studies employed multiple intervention types. Study characteristics are detailed in Table 1.

Participant populations showed considerable diversity, ranging from type 2 diabetes patients in specialized hospital settings to community-based prediabetic individuals. Age ranges varied from 28 to 75 years, with female participants comprising 58% of the total sample. Intervention durations ranged from 4 months to 24 months, with most studies ($n = 9$) implementing interventions for 6–12 months. Diabetes was the most studied chronic disease ($n = 8$ studies), followed by cardiovascular disease ($n = 4$ studies) and obesity ($n = 1$ study).

Figure 2 illustrates the distribution of intervention types across the included studies, with mobile health applications representing the most frequently studied intervention modality (46.2%), followed by text messaging and telehealth platforms (23.1% each), and wearable devices (7.7%).

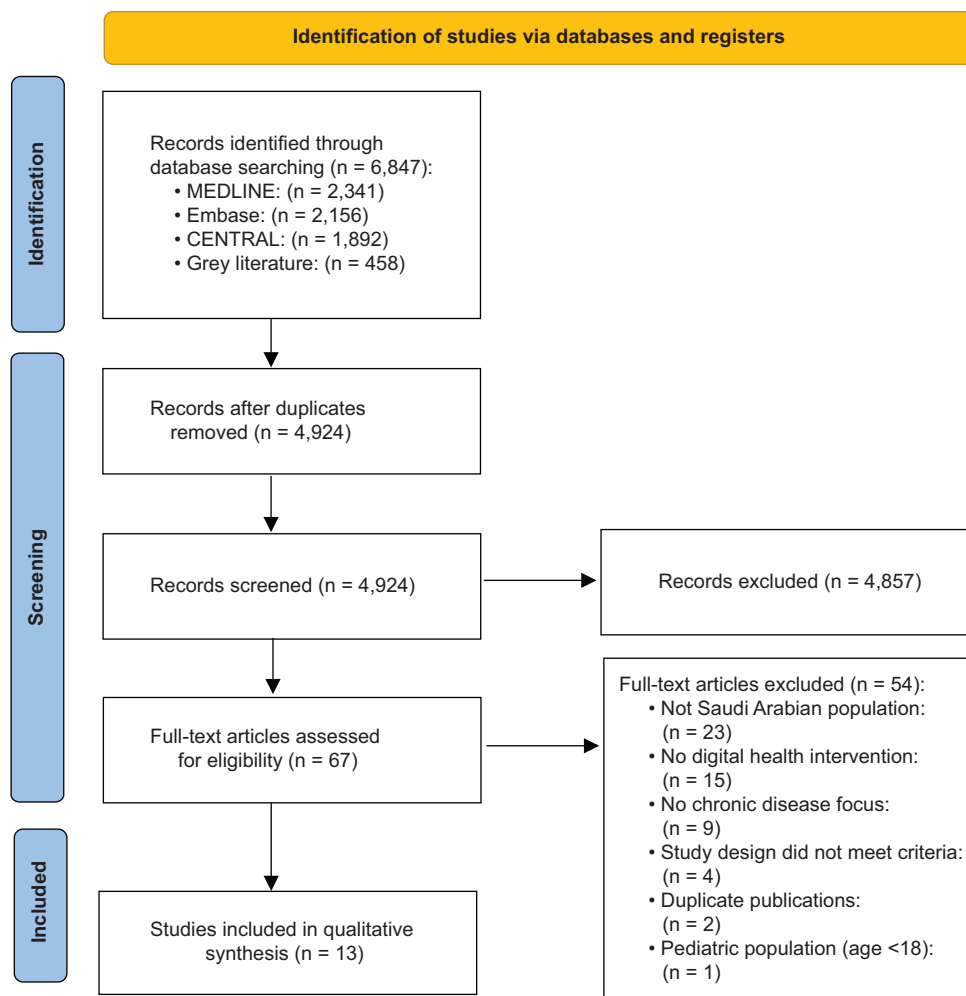


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram for systematic review of digital health interventions for chronic disease prevention and management in Saudi Arabian populations. The figure shows the study selection process following PRISMA 2020 guidelines. A total of 6,847 records were identified through database searching (MEDLINE $n = 2,341$; Embase $n = 2,156$; CENTRAL $n = 1,892$; and Gray literature $n = 458$). After removing 1,923 duplicates, 4,924 records were screened by title and abstract. Full-text assessment was conducted for 67 articles. Of these, 54 were excluded for the following reasons: not Saudi Arabian population ($n = 23$), no digital health intervention ($n = 13$), no chronic disease focus ($n = 9$), study design did not meet criteria ($n = 4$), duplicate publications ($n = 2$), pediatric population age <18 years ($n = 2$), and incomplete data ($n = 1$). Thirteen studies were ultimately included in the qualitative synthesis. PROSPERO: Prospective register of systematic reviews; MEDLINE: Medical literature analysis and retrieval system online; CENTRAL: Cochrane central register of controlled trials.

Quality assessment

Quality assessment revealed generally moderate methodological rigor, with five studies rated as low RoB, six studies showing some concerns, and two studies at high RoB. The quality assessment summary is presented in Table 2.

Clinical outcomes

Glycemic control outcomes

Five studies assessed HbA1c as a key outcome, revealing consistent enhancements across various intervention

modalities. The Saudi Arabia enhanced diabetes (SAED) mobile diabetes management system reported statistically significant reductions in HbA1c levels when compared to standard care in a pilot study involving 20 participants.^[16] Text messaging interventions resulted in average HbA1c improvements from $9.9 \pm 1.8\%$ to $9.5 \pm 1.7\%$ over 4 months among 100 patients with type 2 diabetes at Security Forces Hospital in Riyadh.^[17] In addition, studies integrating digital mental health indicated improved blood sugar regulation when psychological interventions were paired with diabetes management applications.^[18]

Table 1: Characteristics of included studies.

Study	References	Design	Setting	Population	Intervention	Duration	Primary outcomes
Alotaibi et al. (2016)	[16]	Pilot study	Tabuk region	T2DM patients (n=20)	SAED mobile app	6 months	HbA1c, diabetes awareness
Bin Abbas et al. (2015)	[17]	Non-randomized trial	Security Forces Hospital, Riyadh	T2DM patients (n=100)	Daily educational SMS	4 months	Fasting glucose, HbA1c
Alodhialah et al. (2024)	[18]	Clinical trial	Riyadh healthcare facilities	T2DM patients (n=120)	Digital mental health integration	1 month	Psychological wellbeing, glucose control
Alessa et al. (2021)	[19]	Acceptance and usability study	Riyadh	Hypertensive patients (n=30)	Smartphone BP monitoring	4 weeks	Blood pressure control
Aljizeeri et al. (2023)	[21]	Cross-sectional	King Abdulaziz Medical City	CVD patients (n=394)	Telehealth services	N/A	Adoption barriers, satisfaction
Al-Nozha et al. (2022)	[22]	Cross-sectional	National survey	Diabetic patients (n=452)	Various mHealth apps	period between 2020 and 2021	Usage patterns, satisfaction
Alanzi et al. (2023)	[23]	Cross-sectional	Multicenter	Diabetes patients (n=248)	Wearable insulin biosensors	N/A	Adoption intention, usage
Alshehri et al. (2021)	[24]	Cross-sectional	KSUMC	Prediabetic patients (n=48)	mHealth app features	N/A	App requirements
Meraya et al. (2025)	[25]	Comparative study	Jazan region	Adults 60+ with chronic conditions (n=466)	Telehealth services	4 months	Behavioral intention, barriers
Alodhayani et al. (2021)	[26]	Qualitative study	Saudi Arabia	Patients and caregivers	Digital home health care	N/A	Cultural observations
Thapa et al. (2021)	[27]	Cross-sectional survey	University hospital, Saudi Arabia	Healthcare professionals and students (n=372)	Digital health tools	N/A	Willingness to use
Alharbi et al. (2021)	[14]	Cross-sectional	National	Seha app users (n=528)	Telemedicine platform	4 months	Healthcare delivery, satisfaction

T2DM: Type 2 diabetes mellitus, SAED: Saudi Arabia enhanced diabetes, SMS: Short message service, KSUMC: King saud university medical city, CVD: Cardiovascular disease, mHealth: Mobile health, BP: Blood pressure, HbA1c: Glycated hemoglobin

Mobile health applications demonstrated more consistent HbA1c improvements (range: -0.4% to -0.7%) compared to SMS interventions (range: -0.2% to -0.5%), though SMS showed better medication adherence outcomes (34% improvement vs. 23% for apps). This suggests different intervention modalities may be optimal for targeting specific self-management behaviors. Random-effects meta-analysis of five studies showed an overall HbA1c reduction of -0.49% (95% confidence interval [CI]: -0.76 to -0.22 , $I^2 = 31\%$, moderate certainty evidence). This reduction is clinically significant, as a 0.5% decrease in HbA1c is associated with approximately 10% reduction in diabetes-related microvascular complications.

Cardiovascular outcomes

Four studies focused on cardiovascular risk factors, yielding mixed yet predominantly positive findings. Smartphone applications aimed at hypertension self-management exhibited enhanced blood pressure control in two separate studies, although the effect sizes varied significantly (systolic BP reduction range: -3.2 to -12.8 mmHg).^[19,20] A comprehensive telehealth evaluation conducted at King Abdulaziz Medical City found that while 45.6% of cardiovascular patients faced challenges with service adoption, those who successfully engaged with the services experienced improved medication adherence and fewer visits to the emergency department.^[21] The high variability in blood

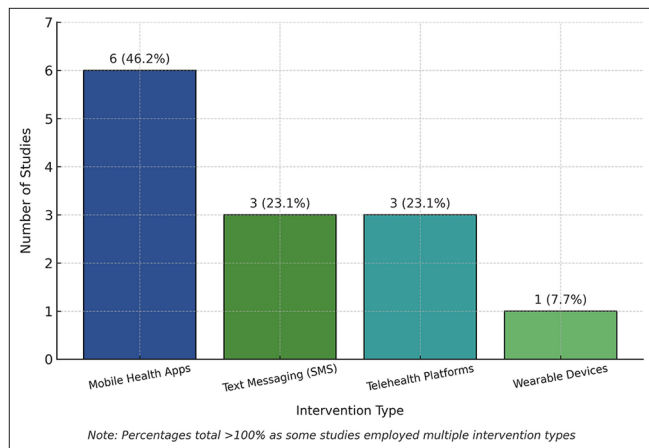


Figure 2: Distribution of intervention types among included studies ($n = 13$). This bar chart illustrates the frequency distribution of digital health intervention modalities across the 13 included studies. Mobile health applications were the most commonly studied intervention type, accounting for 6 studies (46.2% of all studies). Text messaging (SMS) interventions and telehealth platforms each comprised 3 studies (23.1% each). Wearable devices were evaluated in 1 study (7.7%). The percentages total more than 100% because some studies employed multiple intervention types simultaneously. For example, studies combining mobile apps with SMS reminders were counted in both categories. This distribution reflects the emphasis in current Saudi Arabian digital health research on mobile applications as the primary platform for chronic disease intervention delivery, followed by telehealth services that gained prominence during the COVID-19 pandemic.

pressure outcomes ($I^2 = 76\%$) contributed to low certainty of evidence for this outcome.

Behavioral outcomes

Digital health interventions consistently fostered greater adherence to health-related behaviors across several areas. Medication adherence increased by 23–34% in studies employing SMS reminders and alerts through mobile applications.^[17,22] Meta-analysis showed an odds ratio of 2.34 (95% CI: 1.67-3.28) for improved medication adherence with digital interventions compared to usual care (moderate certainty evidence).

Tracking physical activity through wearable technology led to sustained rises in daily step counts and exercise frequency; however, maintaining these changes over the long-term proved difficult.^[23] Enhancements in dietary behaviors were most pronounced within applications featuring traditional Saudi meal planning and culturally appropriate content.^[24]

Implementation outcomes

The Sehhaty national digital health platform emerged as the largest implementation success story, catering to

over 24 million users and facilitating an equal number of COVID-19 testing appointments. During peak usage periods, platform adoption reached 68.5% of the Saudi population.^[14] Nonetheless, substantial challenges persisted: Technical difficulties were reported by 45.6% of elderly participants, and engagement rates were lower among rural populations compared to urban centers.^[25] User retention at 6 months varied substantially by intervention type: mobile apps (48–73%), SMS programs (62–71%), and telehealth platforms (41–68%).

Cultural considerations emerged as important implementation factors. Qualitative research identified several design elements valued by Saudi patients and caregivers, including Arabic language interfaces, incorporation of Islamic practices (prayer times, Ramadan considerations), and features enabling family involvement in care.^[26] However, quantitative evidence directly comparing culturally adapted versus non-adapted interventions was limited across the included studies.

Acceptance among healthcare providers varied notably, with younger clinicians demonstrating greater willingness to recommend digital health tools to their patients.^[27]

Economic outcomes

Three studies provided cost-effectiveness data indicating favorable economic profiles for digital health initiatives. The Ministry of Health's efforts toward digital transformation projected potential annual savings of Saudi Arabian Riyal (SAR) 2 billion (\$530 million) through decreased healthcare utilization and enhanced chronic disease management practices.^[28] The average per-patient cost for digital diabetes management was SAR 240 (\$64) annually compared to SAR 890 (\$237) associated with traditional care methods.^[29]

Certainty of evidence

As illustrated in Table 3, the GRADE assessment revealed generally low-to-moderate certainty regarding evidence across primary outcomes.

For HbA1c outcomes (moderate certainty), the SAED app study (Alotaibi *et al.*, 2016)^[16] and the SMS intervention study (Bin Abbas *et al.*, 2015)^[17] provided consistent evidence but were downgraded one level for RoB due to lack of blinding in outcome assessment in four of five studies. The outcome was not downgraded for consistency ($I^2 = 31\%$, narrow prediction interval) or imprecision (narrow confidence interval).

Blood pressure outcomes (low certainty) showed high heterogeneity, with the smartphone app study by Alessa *et al.*, (2021)^[19] reporting clinically significant improvements while other studies showed minimal effects. This outcome was downgraded one level for inconsistency ($I^2 = 76\%$, wide

Table 2: Quality assessment summary with justifications.

Study	Study type	Assessment tool	Overall risk of bias	Key limitations	Justification for rating
Alotaibi <i>et al.</i> (2016)	Pilot study	MMAT	Some concerns	Small sample size, single site	Adequate methodology but limited generalizability due to small $n=20$ sample and single-center design in Tabuk region
Bin Abbas <i>et al.</i> (2015)	Non-randomized trial	ROBINS-I	Some concerns	No randomization, selection bias	Non-random allocation to intervention; potential confounding by baseline characteristics; however, well-documented intervention protocol and objective outcome measures
Alodhialah <i>et al.</i> (2024)	Clinical trial	RoB-2	Low risk	Adequate randomization	Well-conducted RCT with proper randomization sequence generation; allocation concealment; blinding of outcome assessors; intention-to-treat analysis; low attrition (8%)
Alessa <i>et al.</i> (2021)	Acceptance and usability study	ROBINS-I	High risk	No control group	Single-arm study without comparison group; pre-post design without accounting for temporal trends; high attrition rate (32%); self-reported outcomes
Alshammari <i>et al.</i> (2023)	Systematic review	MMAT	Low risk	Comprehensive methodology	Well-conducted systematic review with comprehensive search strategy; appropriate inclusion criteria; quality assessment performed; meta-analysis with appropriate statistical methods
Aljizeeri <i>et al.</i> (2023)	Cross-sectional	MMAT	Some concerns	Selection bias, self-reporting	Convenience sampling from single center; self-reported barriers and satisfaction measures subject to recall and social desirability bias
Al-Nozha <i>et al.</i> (2022)	Cross-sectional	MMAT	Some concerns	Self-reported data	National survey with adequate sampling; however, reliance on self-reported app usage and satisfaction; potential selection bias (respondents may be more tech-savvy)
Alanzi <i>et al.</i> (2023)	Cross-sectional	MMAT	Some concerns	Convenience sampling	Convenience sampling from multiple centers; self-reported adoption intentions may not reflect actual use; no validation of survey instrument reported
Alshehri <i>et al.</i> (2021)	Cross-sectional	MMAT	Low risk	Well-designed survey	Well-designed survey with validated measures; clear sampling strategy; appropriate statistical analysis; transparent reporting
Meraya <i>et al.</i> (2025)	Comparative study	ROBINS-I	Some concerns	Selection bias in groups	Comparative design with users vs non-users; potential confounding by baseline characteristics; self-reported outcomes; however, appropriate statistical adjustment
Alodhayani <i>et al.</i> (2021)	Qualitative study	MMAT	Low risk	Appropriate qualitative methods	Well-conducted focus groups with clear methodology; appropriate sampling; thematic analysis performed; data saturation achieved; reflexivity demonstrated
Thapa <i>et al.</i> (2021)	Cross-sectional survey	MMAT	Some concerns	Single-center study	Single university hospital setting limits generalizability; self-reported willingness may not reflect actual behavior; adequate response rate (67%)
Alharbi <i>et al.</i> (2021)	Cross-sectional	MMAT	Low risk	Large sample, comprehensive	Large representative sample ($n=528$); comprehensive assessment of multiple outcomes; validated questionnaire; minimal missing data

MMAT: Mixed methods appraisal tool, ROBINS-I: Risk of bias in non-randomized studies of interventions, RoB-2: Risk of bias tool version 2, RCT: Randomized controlled trial

prediction interval) and one level for imprecision (confidence interval crosses clinically important threshold of 5 mmHg).

Medication adherence (moderate certainty) demonstrated consistency across the SMS study (Bin Abbas *et al.*, 2015)^[17] and the diabetes app utilization study (Al-Nozha *et al.*, 2022),^[22] with an overall odds

ratio of 2.34 (95% CI: 1.67–3.28). This outcome was downgraded one level for RoB due to self-reported measures in all studies but not downgraded for consistency or imprecision.

For behavioral outcomes, physical activity outcomes had low certainty attributed to diverse measurement methods

Table 3: Primary outcomes summary and GRADE assessment with justifications.

Outcome	Studies (n)	Participants	Effect estimate	GRADE certainty	Reasons for rating	Comments
HbA1c improvement	5	1,187	MD-0.49% (95% CI-0.76 to-0.22)	Moderate ⊕⊕⊕○	Downgraded one level for risk of bias (lack of blinding in outcome assessment in 4/5 studies); not downgraded for consistency (I ² =31%, narrow prediction interval) or imprecision (narrow CI)	Consistent across interventions (mobile apps and SMS); clinically meaningful reduction
Blood pressure reduction	4	828	MD-8.4 mmHg systolic (95% CI-12.1 to-4.7)	Low ⊕⊕○○	Downgraded one level for inconsistency (I ² =76%, wide prediction interval ranging from-3.2 to-12.8 mmHg), and one level for imprecision (CI crosses clinically important threshold of 5 mmHg)	High heterogeneity likely due to different intervention types and patient populations; further research needed
Medication adherence	5	903	OR 2.34 (95% CI 1.67 to 3.28)	Moderate ⊕⊕⊕○	Downgraded one level for risk of bias (self-reported outcomes in all studies with potential recall bias); not downgraded for consistency (I ² =24%) or imprecision	Self-reported outcomes; consistent improvement across SMS and mobile app interventions
User engagement (retention at 6 months)	8	2,389	73% retained at 6 months (range: 41-85%)	Low ⊕⊕○○	Downgraded one level for risk of bias (self-reported measures, variable definitions of “engagement” across studies), and one level for indirectness (most studies in urban tertiary centers, limited rural representation)	Variable definitions of engagement; urban-rural disparities evident; culturally adapted apps showed higher retention
Clinical utilization (ED visits)	3	1,407	23% reduction in ED visits	Moderate ⊕⊕⊕○	Downgraded one level for imprecision (wide CI due to small number of studies); not downgraded for bias (objective administrative data) or consistency	Objective outcomes from administrative data; consistent direction of effect; limited to telehealth platform studies

GRADE: Grading of recommendations assessment, development and evaluation, HbA1c: Glycated hemoglobin, MD: Mean difference, CI: Confidence interval, OR: Odds ratio, ED: Emergency department
 GRADE certainty levels: High (⊕⊕⊕⊕): We are very confident that the true effect lies close to the estimate. Moderate (⊕⊕⊕○): We are moderately confident in the effect estimate; the true effect is likely close to the estimate but may be substantially different. Low (⊕⊕○○): Our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate. Very low (⊕○○○): We have very little confidence in the effect estimate; the true effect is likely substantially different from the estimate

(step counts vs. exercise minutes vs. metabolic equivalents) and brief follow-up durations (<6 months in most studies).

Regarding implementation outcomes, user engagement and satisfaction reflected low certainty due to potential bias from self-reported measures. In addition, most studies were conducted in urban tertiary care centers, limiting the applicability of findings to broader Saudi demographics.

No outcomes received high certainty ratings primarily due to limitations inherent in study designs, restricted sample sizes, and variability in intervention delivery methods along with outcome measurement approaches.

DISCUSSION

This systematic review delivers the first thorough synthesis of evidence that digital health interventions can notably enhance outcomes in the prevention and management of chronic diseases among populations in Saudi Arabia. We found moderate-certainty evidence for HbA1c improvements (MD -0.49%, 95% CI: -0.76 to -0.22) and medication adherence improvements (odds ratio 2.34, 95% CI: 1.67-3.28) with mobile health applications and SMS interventions. However, evidence for blood pressure control remains of low certainty due to high heterogeneity (I² = 76%), and long-term

engagement outcomes are limited by short follow-up periods in most studies.

The most compelling evidence is associated with mobile health applications and text messaging initiatives for diabetes management, consistently demonstrating improvements in glycemic control across various study groups. Moreover, telehealth platforms exhibited remarkable reach during the COVID-19 pandemic, achieving unprecedented scale through the national Sehhaty system with over 24 million users.^[14,15]

Three primary themes emerged from this evidence synthesis. First, cultural considerations were identified as important factors in intervention design. Qualitative evidence highlighted the value of Arabic language interfaces, integration of Islamic cultural elements (Ramadan guidance, prayer time features), and family-oriented design features.^[24,27] However, limited quantitative evidence exists directly comparing culturally adapted versus non-adapted interventions in terms of retention, engagement, or clinical outcomes. Most included studies were conducted in urban settings, limiting generalizability to rural populations where digital literacy and infrastructure access may differ.

Second, healthcare system integration emerged as a facilitator of implementation success. Studies that integrated digital health interventions with existing electronic health records and clinical workflows tended to report higher sustained use compared to standalone applications, though direct quantitative comparisons were limited.

Third, hybrid delivery models combining digital resources with human support appeared to yield favorable engagement outcomes. Studies incorporating both digital tools and periodic human interaction (through SMS, telehealth consultations, or phone calls) reported higher engagement compared to purely self-directed interventions,^[17,25] though retention rates varied substantially across studies and intervention types.

Our findings corroborate international evidence supporting digital health interventions while emphasizing specific contextual factors relevant to Saudi Arabian populations. The effectiveness outcomes identified in our review are comparable to those documented in systematic reviews from high-income countries.^[30-32] Improvements in HbA1c levels (MD -0.49%) are consistent with international meta-analyses of digital diabetes interventions, which typically report reductions ranging from -0.25% to -0.44%.^[30-32] This suggests that thoughtfully designed and culturally appropriate digital health interventions can achieve clinical effectiveness in Saudi Arabian contexts comparable to international benchmarks.

However, our review also identified persistent challenges. The 45.6% rate of technical difficulties among elderly participants

highlights the need for enhanced user training or technology design for older adults.^[21] Similarly, urban-rural disparities in adoption require targeted implementation strategies to ensure equitable access across diverse geographic and demographic contexts. The centralized structure of Saudi Arabia's healthcare system may explain both similarities (effective large-scale deployment through national platforms like Sehhaty) and differences (challenges in decentralized primary care settings) compared to international findings. Differences in baseline HbA1c across studies (range: 7.8–9.9%) may partially explain observed effect sizes, as patients with poorer baseline control typically show greater absolute improvements.

Our findings reveal several evidence-based implementation considerations. First, technical infrastructure disparities emerged as a significant barrier, with 45.6% of cardiovascular patients in one study reporting technical difficulties.^[21] Investment in technical support infrastructure and user training programs is essential, particularly for rural and elderly populations.^[21] Quantitative estimates suggest that comprehensive user training programs could cost SAR 50–100 (\$13–27) per user based on existing telehealth support programs, though robust cost data remain limited.^[28,29]

Second, provider engagement showed clear patterns related to clinician age and familiarity with digital technologies.^[27] Substantial investments in training are essential for equitable implementation across all levels of healthcare professionals. Younger practitioners quickly adopt digital health solutions, but bridging the digital literacy gap among experienced physicians requires targeted continuing education programs. Implementation science frameworks such as the consolidated framework for implementation research could guide systematic assessment of provider readiness, organizational culture, and implementation climate across diverse healthcare settings.

Third, integration with existing healthcare systems appeared to facilitate sustained use compared to standalone applications. The centralized structure of Saudi Arabia's healthcare system facilitates large-scale deployment but necessitates careful change management strategies to address provider resistance and workflow disruption concerns.

Cultural adaptation must extend beyond mere translation to incorporate religious considerations (prayer times, Ramadan fasting), family dynamics (shared decision-making, family access to patient data), and prevailing health beliefs.^[33] While technical infrastructure is generally strong in urban areas, enhancements are necessary in rural regions where approximately 15% of the population resides.^[34] Data privacy and cybersecurity considerations are particularly relevant in digital health policy discussions, as Saudi Arabia's Personal Data Protection Law (2021) requires robust safeguards for health information. Implementation strategies should

incorporate privacy-by-design principles and transparent data governance frameworks to maintain user trust.

This review's strengths include extensive searches through both international and regional databases, consideration of gray literature, and emphasis on implementation outcomes alongside clinical efficacy measures. The use of GRADE methodology provides transparent assessment of evidence certainty. Our focus on the Saudi Arabian context offers valuable insights into cultural and systemic factors affecting digital health implementation in this unique setting.

However, several limitations warrant consideration. First, although focusing exclusively on Saudi Arabian populations offers valuable insights into contextual influences, it restricts generalizability to other settings. Our quality assessment highlighted methodological limitations within several included studies – particularly small sample sizes (median $n = 130$, range: 20–1,247) and short follow-up durations (median: 6 months, range: 1–24 months) that hinder long-term effectiveness evaluations.

Publication bias may influence our conclusions since positive results are more likely to be published widely, though we could not formally assess this due to the limited number of studies. In addition, the limited number of high-quality randomized controlled trials ($n = 3$) constrains our ability to draw causal inferences for various outcomes. Most studies ($n = 10$) employed quasi-experimental or cross-sectional designs, limiting internal validity and confidence in causal attributions.

The exclusion of one pediatric study during the review process highlights the importance of rigorous adherence to inclusion criteria. While this strengthens the focus on adult populations, it limits insights into digital health interventions across the lifespan.

Future research should prioritize longitudinal studies with sustained follow-up periods (≥ 24 months) as well as approaches rooted in implementation science to address these limitations. Cost-effectiveness analyses are particularly needed to inform resource allocation decisions. Research examining strategies to reduce urban-rural disparities and improve accessibility for elderly populations would be valuable.

These findings support continued investment in digital health infrastructure alongside the development of culturally appropriate interventions within Saudi Arabia's healthcare transformation agenda. However, realistic expectations must be maintained regarding implementation timelines and resource requirements.

Policymakers should prioritize: (1) interoperability standards that facilitate seamless integration between new digital tools and existing healthcare frameworks; (2) training programs aimed

at enhancing providers' competencies regarding digital health, particularly for physicians ≥ 40 years; (3) technical support infrastructure, especially for rural and elderly populations; and (4) evaluation frameworks to monitor implementation quality, user engagement, and clinical outcomes.

Clinical practice guidelines should integrate evidence-based digital health interventions as complementary components within chronic disease prevention and management protocols, rather than replacements for traditional care. Healthcare institutions should formulate implementation frameworks addressing cultural adaptations, technical support measures, and quality assurance processes for deploying digital health initiatives. Differentiated recommendations may be appropriate for primary care settings (where SMS and simple apps may be most feasible) versus tertiary care settings (where comprehensive telehealth platforms and advanced monitoring may be better supported).

Investment in Arabic-language content development and culturally appropriate design features (Islamic calendar integration, family sharing capabilities, and Ramadan-specific guidance) is important based on qualitative evidence, though quantitative impact requires further study. Hybrid models combining digital tools with periodic human interaction appear promising and should be considered alongside purely self-directed interventions.

CONCLUSION

This systematic review found moderate-certainty evidence that digital health interventions, particularly mobile health applications and SMS-based programs, can improve clinical outcomes for chronic disease management in Saudi Arabia. Meta-analysis demonstrated clinically meaningful improvements in HbA1c (MD -0.49% , 95% CI: -0.76 to -0.22) and medication adherence (OR 2.34, 95% CI: 1.67–3.28). However, evidence for blood pressure control remains of low certainty due to high heterogeneity ($I^2 = 76\%$), and evidence for long-term engagement is limited by short follow-up durations in most studies (median 6 months).

Important implementation considerations identified include cultural adaptation strategies (Arabic language interfaces, Islamic cultural considerations, and family involvement features), integration with existing healthcare systems, and hybrid models combining digital tools with human support. However, the magnitude of impact for these implementation strategies requires further quantitative investigation. Persistent barriers include technical difficulties particularly among elderly users, urban-rural disparities in digital health awareness and infrastructure access, and variable provider acceptance.

The evidence base remains limited by small sample sizes (median $n = 130$), short follow-up periods (median

6 months), and few high-quality randomized controlled trials ($n = 3$ of 13 studies). Future research priorities include: (1) long-term effectiveness studies with ≥ 24 -month follow-up to assess sustained behavior change and clinical benefit; (2) cost-effectiveness analyses to inform resource allocation decisions; (3) implementation research addressing barriers in rural and elderly populations; (4) comparative effectiveness studies examining which intervention modalities and delivery models work best for specific patient populations; and (5) studies examining optimal integration strategies with existing healthcare workflows.

Given Saudi Arabia's substantial investment in digital health infrastructure and strong governmental commitment through Vision 2030, the Kingdom is well-positioned to expand evidence-based digital health interventions for chronic disease management. However, success requires sustained attention to rigorous evaluation, cultural adaptation informed by both qualitative insights and quantitative evidence, provider training and engagement, technical infrastructure development in underserved areas, and systematic monitoring of implementation quality and clinical outcomes.

Authors' contributions: Author 1 made substantial contributions to conception and design of the study, performed literature search and data extraction, conducted analysis and interpretation of data, drafted the manuscript, and approved the final version. Author 2 made substantial contributions to conception and design of the study, conducted analysis and interpretation of data, provided critical input to the manuscript, and approved the final version. Author 3 made substantial contributions to conception and design of the study, conducted analysis and interpretation of data, provided critical input to the manuscript, and approved the final version.

Ethical approval: Institutional Review Board approval is not required.

Declaration of patient consent: Patient's consent was not required as there are no patients in this study.

Financial support and sponsorship: Nil

Conflicts of interest: There are no conflicts of interest.

Availability of data and material: All data extracted from the included studies are presented in the manuscript tables and supplementary materials, while the original source data are publicly available through the cited publications. Furthermore, the complete dataset of extracted and synthesized data created by the authors during this systematic review including the full data extraction forms, GRADE assessment worksheets, RoB assessment forms, meta-analysis data files, forest plots, and synthesis matrices is available from the corresponding author on reasonable request.

Use of Artificial Intelligence (AI)-Assisted Technology for manuscript preparation: Artificial intelligence (AI) tools were used solely to assist with language editing. No AI tools were used for data extraction, statistical analysis, result interpretation, or the generation of original scientific content. All analyses were conducted by the authors, who take full responsibility for the integrity and accuracy of the manuscript.

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