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Mobile applications for non-communicable disease Management: A systematic review of development methods and effectiveness

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ABSTRACT

Aim: To evaluate the most effective development methods for mobile applications that support self-management of non-communicable diseases and to determine the features that enhance their effectiveness and user adoption.
Methods: The design was a systematic review of research papers published in the period 2019–2024. The review included randomized and quasi-experimental clinical trials. The search was performed in six databases (PubMed, Scopus, Scielo, CINAHL, Web of Science, and Clinical Trials). Bias and methodological quality were assessed using the RoB2 and MINORS tools.
Results: The review included six studies involving 2421 patients across four countries. The applications demonstrated improvements in treatment adherence, self-efficacy, and control of clinical variables such as glycemia and blood pressure. The most effective applications incorporated therapeutic education, monitoring, and reminders. However, limitations were noted, including insufficient user involvement in early development stages, which could affect relevance and usability. The heterogeneity of study designs and populations, coupled with the lack of large-scale clinical trials, limits the generalizability of the findings. Additionally, variability in technological platforms and the absence of standardized evaluation metrics complicate outcome comparisons.
Conclusion: Mobile applications for chronic disease self-management are most effective when developed with a user-centered approach and continuous validation. Despite these findings, further research is necessary to generalize the results and optimize the integration of these applications into healthcare systems.
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1. Introduction

Chronic non-communicable diseases (NCDs), including cardiovascular diseases such as heart failure, chronic respiratory diseases (COPD), cancer, and diabetes, are the leading cause of death and morbidity worldwide, with significant social and economic effects [1,2]. These pathologies not only affect patients' quality of life but also burden healthcare systems considerably. In addition, the aging of the population and rising healthcare costs have raised concerns, especially in developed countries, about how to effectively manage these diseases [3]. Adequate follow-up of chronic pathologies is crucial to improve patients' quality of life and prevent complications [2].

In response to the increasing demand for health services, there is a need to evaluate the benefits of lifestyle modifications and patient participation in health-related decisions. Strategies such as self-management focused on behavioral changes, educational interventions, and motivation for self-care be effective in promoting these modifications [4].

Technology presents itself as a promising solution to bridge the gap between the needs of chronically ill patients and the capabilities of health systems [5]. Mobile applications, due to their wide accessibility and low cost, have become essential tools for real-time monitoring,

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improving treatment adherence, and facilitating communication between patients and healthcare professionals [2].

Evidence suggests that mobile applications designed for chronic disease management can significantly improve health outcomes when they incorporate functionalities such as medication reminders, educational content, symptom monitoring, and interactive communication tools [6]. Studies on mobile health interventions for diabetes management have shown that integrating self-monitoring features, real-time feedback, and tailored educational modules improves glycemic control, medication adherence, and patient engagement [6,7]. A recent study analyzing key elements of mobile applications for self-care in diabetes highlighted the importance of integrating comprehensive tracking tools, structured educational content, and personalized feedback to enhance patient adherence and disease management [8].

Despite these advancements, there is still a lack of consensus on the most effective development methods for these applications. While numerous mobile health apps have been created, limited research evaluates which design strategies and functionalities lead to better user engagement, adherence, and clinical outcomes [9,10]. Furthermore, studies often focus on specific conditions, making it challenging to generalize best practices across chronic diseases [9].

Addressing this gap is essential to ensure that future applications are based on solid evidence and user-centered principles. For self-care interventions to be effective and sustainable, it's vital to develop them systematically, grounded in a thorough understanding of patients' needs and considering the complexities of chronic disease management. This necessitates the integration of the best available evidence and appropriate theories, along with adherence to participatory design principles that incorporate the perspectives of all stakeholders [1].

To maximize the impact of these technologies, it is essential to focus on user-centered design and providing continuous training and support, ensuring that applications are both accessible and effective in the long term. Thus, the goal of this systematic review is to identify the most effective development methods for creating mobile applications for chronic disease self-management and to determine which features and functionalities of these applications contribute most significantly to their effectiveness and user adoption.

2. Methods

2.1. Study design and search strategy

This systematic review was conducted to evaluate the most effective development methods for mobile applications focused on chronic disease self-management. The study adhered to PRISMA guidelines and the Cochrane Handbook for Systematic Reviews of Interventions. The research question was formulated using the PICO framework to identify optimal development methods for mobile app creation in this context [11,12].

The PICO strategy was used to develop research questions.

- What is the development method that has demonstrated the best results in the creation of mobile applications aimed at self-management of chronic diseases?
- What features and functionalities of mobile applications developed for chronic disease self-management contribute to better results in their effectiveness and user adoption?

A comprehensive search strategy was developed using Medical Subject Headings (MeSH) and free-text terms. Keywords included "mobile health apps," "chronic diseases," "app design," "prototype development," and "health technology." Boolean operators "AND" and "OR" were used to refine the search. The search was conducted across six databases, covering the period from 2019 to 2024.

No language restrictions were applied, and gray literature from Clinical Trials records was included to ensure comprehensive coverage. A review of bibliographic references of selected studies was also performed to identify additional relevant studies.

2.2. Data sources

The data sources for this systematic review included research across six major databases: PubMed, Scopus, Scielo, CINAHL, Web of Science, and Clinical Trials. These databases were chosen to ensure wide coverage of relevant literature in health sciences and technology. The search strategy incorporated both MeSH and free-text terms to capture a broad range of studies related to mobile health applications and chronic disease management.

Along with peer-reviewed journal articles, gray literature from Clinical Trials records was included to account for unpublished or ongoing studies, thereby minimizing publication bias and providing a comprehensive evidence base.

2.3. Study selection

Articles were selected according to the following inclusion criteria: (a) randomized clinical trials, observational and quasi-experimental studies (b) studies describing the development of mobile applications for the management of chronic diseases with standardized management in Primary Care (Diabetes, obesity, asthma, Chronic Obstructive Pulmonary Disease, Heart Failure, Chronic Kidney Disease, heart disease and Arterial Hypertension); c) studies that included aspects of design, development, creation, framework or implementation of such applications; d) health outcomes such as improvements in medical care, adherence to treatment, or management of chronic diseases.

Studies that required the use of sensors or other specific devices to work with the application were excluded, as well as those that focused only on a specific aspect of chronic pathologies, such as diabetic foot or physical exercise in a specific disease.

2.4. Data extraction

Fig. 1 shows a PRISMA diagram summarizing the selection process. Initially, 1028 articles were identified across six databases. After eliminating duplicates, 816 articles were selected. Titles and abstracts were individually inspected to identify documents relevant to the study, excluding 669 studies.

Duplicate records were identified and removed before the screening phase using Mendeley (Elsevier), a reference management software. Its built-in tool compares key bibliographic fields such as title, authors, publication year, and journal to detect potential duplicates. This process resulted in the elimination of 212 entries, all of which were manually verified to ensure accuracy and prevent erroneous exclusions. The subsequent eligibility assessment was conducted independently by two reviewers. Discrepancies were resolved through discussion and, when necessary, adjudicated by a third reviewer, thereby enhancing the rigor and reliability of the review process.

Subsequently, 49 full-text studies were analyzed, and 43 were excluded for not meeting the eligibility criteria. The main reasons for exclusion included a lack of reported results, no description of the app design process, not fitting the type of intervention, and failing to meet methodological quality standards. Additionally, some studies, although described as randomized controlled trials (RCTs), reported only usability outcomes instead of clinical results, suggesting they were still in early developmental phases. The review and analysis were conducted independently by peers, and any discrepancies were resolved by a third independent reviewer.

The review and analysis were performed independently by peers, and any discrepancies were resolved by a third independent reviewer. Data extraction included country, publication type, study objective, APP design process, results, and methodological quality.

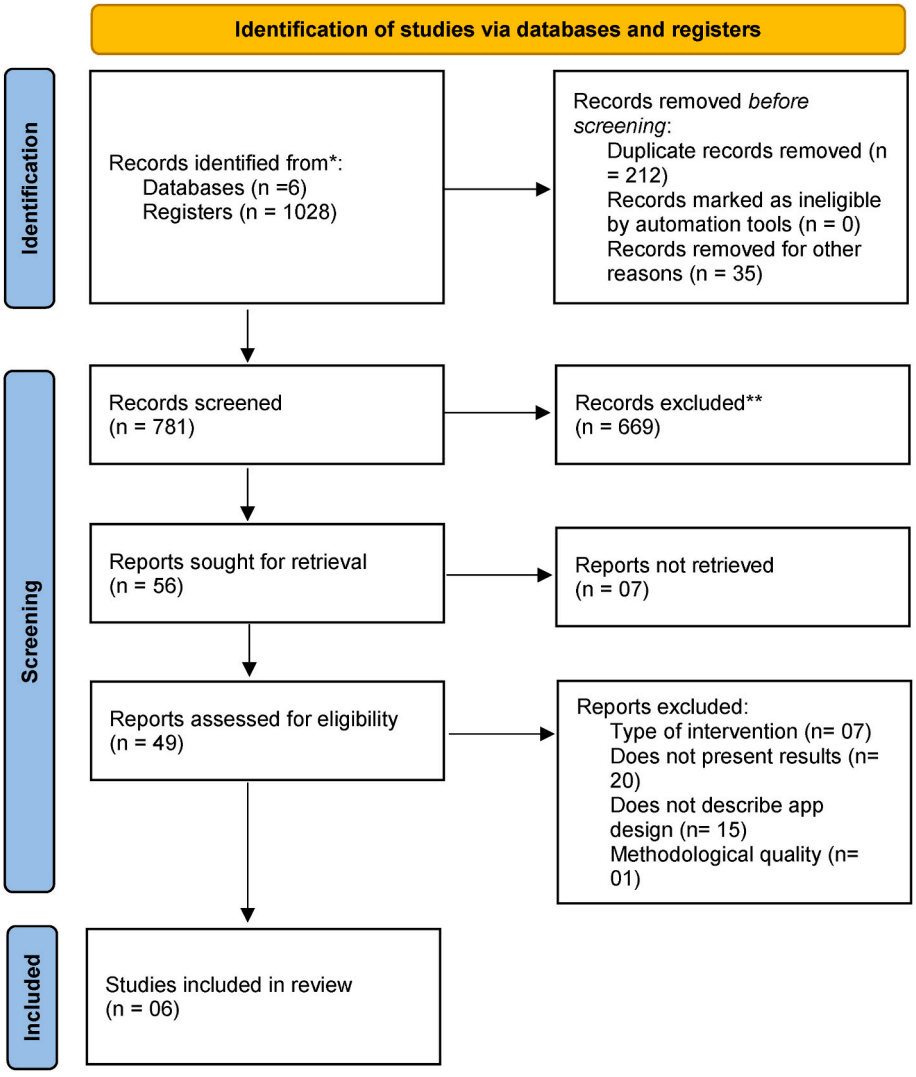

Fig. 1. PRISMA Flow diagram.

2.5. Data synthesis

The data synthesis involved a qualitative analysis of the selected studies to identify common themes and patterns in the development methods of mobile applications for chronic disease self-management. The synthesis focused on evaluating the effectiveness of different design approaches, such as user-centered design and participatory methods, and their impact on user engagement and health outcomes. Key features and functionalities that contributed to the success of these applications were also identified, including educational content, reminders, and symptom monitoring. The findings were integrated to provide insights into best practices for app development in this field.

2.6. Quality and risk of bias assessment

During the selection process, an evaluation of the methodological quality of the selected studies was carried out using the Jadad scale criteria [13]. This tool assigns a score to randomized clinical trials (RCTs) ranging from 0 to 5, taking into account randomization and its procedure, type, and method of blinding, as well as losses and withdrawals of study participants. Studies with a score below 3 were considered to have low methodological quality.

Additionally, a risk of bias assessment was conducted using the Cochrane RoB 2.0, tool to evaluate bias in randomized clinical trials [14]. This assessment and the methodological quality of the studies underwent peer review.

This tool examines several specific domains related to the design, execution, and presentation of trial results. The types of bias assessed included: selection bias (related to randomization sequence and allocation concealment), execution bias (related to masking of participants and staff), detection bias (masking of outcome assessors), attrition bias (due to incomplete outcome data), and reporting bias (arising from selective reporting of results). Other types of bias, such as recruitment bias, were also considered. Biases were classified into three categories: "low risk of bias", "uncertain risk of bias" or "high risk of bias".

On the other hand, the quality of the quasi-experimental studies was assessed using the MINORS tool (Methodological Index for Non-Randomized Studies) [15]. MINORS is a tool designed to evaluate the methodological quality of nonrandomized studies, assessing 12 items, 8 of which apply to studies without a control group and 4 additional items for studies with a control group. The items include criteria such as clarity in the definition of objectives, adequacy of follow-up, statistical methodology used, and the existence of well-defined inclusion criteria. Each item is scored from 0 to 2, with a maximum score of 16 for studies without a control group and 24 for studies with a control group. A high score indicates higher methodological quality.

3. Results

Table 1 shows the 6 studies analyzed, where the main characteristics can be identified. Four different countries were identified (Germany [16], China [17], Jordan [18]' and USA. [19–21]). The study designs included three quasi-experimental [18,20,21] one prospective observational study that included elements of a randomized controlled trial [15] and two RCTs [17,19]. Sample sizes ranged from 18 to 2072 participants, totaling 2421 patients. The mean ages of the participants ranged from 24.41 to 66 years. In terms of sex, the percentage of women ranged from 28 % to 90 %. Of the selected studies, half were single-center studies carried out in hospitals, and half were multicenter [18–20] of the selected studies, half were single-center studies carried out in hospitals, and half were multicenter studies, of which one was carried out in hospitals, another was carried out in several hospitals, and another was carried out in several hospitals [17], one was conducted in hospitals, another was conducted in several primary care centers, and the last was conducted in hospitals [16] and the last one was carried out in both settings (primary care and hospital care) [21].

Follow-up time to assess the usefulness of the apps ranged from 1 to 24 months, with a mean of 8 months.

The chronic diseases studied with the apps were COPD [20], DM [17, 18,21], and HYPERTENSION [19] and one of the studies combined multiple pathologies (COPD, DM, HT, and HF) [16].

Regarding the application development process, it primarily followed a user-centered approach that involved the active participation of both experts and patients. Alharbey et al. designed "MyLung" utilizing iterative cycles of validation and refinement based on the literature and the health belief model. Breckner et al. developed "TelePraCMan" through focus groups, interviews, and questionnaires with healthcare professionals and patients. Masadeh et al. created their application based on educational content validated by diabetes experts, while Buis et al. relied on previous experiences to develop "MI-BP." Sittig et al. also emphasized developing their "capABILITY" application through focus groups involving physicians and patients. Finally, Zhang et al. employed iterative design processes among app users for their "SMARTDiabetes" application, alongside a needs analysis based on behavior change theories and a review of clinical guidelines.

As for the apps, they all included therapeutic education, reminders, and alerts, and some had symptom monitoring [16–21], some had symptom monitoring [16,17,20], another had remote appointment management [16] and another included motivational messages [21].

Outcomes were measured in terms of self-efficacy [18–21], self-awareness, and perceived self-efficacy, awareness and perceived severity [20], quality of life [16], patient activation [16], physical exercise [19–21],diet [19,21], knowledge [21] self-care agency [18], self-care [18,21], adherence to medication [20] and control of clinical variables such as blood glucose, HbA1c, blood pressure and lipids [17, 19,21].

Fig. 2 shows the assessment of bias for individual RCTs. All studies have a high risk of bias in the participant masking domain. Table 2 shows the individual risk of bias assessment of the quasi-experimental studies, which was 19 in the two included studies.

4. Discussion

This review aimed to analyze the effectiveness of mobile applications in the self-management of chronic diseases, with a particular focus on the development and design methods used in the studies reviewed. One of the most discussed problems in the use of health applications is the reliability and accuracy of the information they contain, especially because they must be used in the long term by both patients and professionals. This aspect is fundamental to ensure the effectiveness of the applications over time, as shown by the analysis carried out by Camino Ortega et al. [22] which highlights the importance of digital therapeutic education in improving self-care and reducing readmissions in patients with heart failure.

It was observed that applications developed through iterative design and validation cycles based on the literature, such as that of Alharbey et al. [20] showed significant effectiveness in improving self-efficacy. Others, such as Masadeh et al. [18] who designed their application based on educational content validated by diabetes experts, also resulted in improved self-care by patients. However, Buis et al. [19] who used previous experiences for the development of the application, failed to demonstrate a significant improvement in patients compared to the control group. This suggests that applications lacking real-time feedback, adaptive goal setting, or personalized interventions may struggle to maintain long-term user engagement, as users may not feel sufficiently supported throughout their self-management process. Similarly, Breckner et al. [16] identified that mHealth interventions often fail when they do not integrate behavioral trigger messages or provide continuous motivation to the user. For example, Ju et al.[26] highlighted that mobile health applications with integrated human coaching showed better adherence rates compared to fully automated interventions, reinforcing the importance of ongoing support mechanisms in digital health tools.

This aligns with the findings of Zhang et al. [17], who emphasized that digital interventions incorporating real-time monitoring and patient-centered feedback yielded better clinical outcomes. In the same vein, Masadeh et al. [18] demonstrated that diabetes self-management applications integrating tailored educational content and behavioral strategies were more effective in improving self-efficacy and treatment adherence. In contrast, Sittig et al. [21] demonstrated that mobile apps incorporating behavioral trigger messages significantly improved self-management and engagement in patients with diabetes.

Others, such as the study by Zhang et al. [17], which, by integrating a needs analysis, theories of behavioral change, and continuous feedback from experts and patients, resulted in a tool that was better adjusted to the specific needs of the users and obtained a relative improvement of 20 % in variables such as glycemia, blood pressure, and cholesterol. This is in agreement with Martínez-Moreno et al. [23] who reinforce the idea that the collaboration of professional experts during the design and development of mobile applications for the management of chronic diseases significantly improves the quality of the information they contain.

Similarly, applications such as those of the studies by Breckner et al. [16] and Sitting et al. [21], developed through focus groups and interviews with physicians and patients, stood out for their ability to manage multiple chronic diseases, improving communication between patients and professionals. This coincides with the observations of Fernández-Gutierrez et al. [24] who emphasize that the inclusion of user stories facilitates a common understanding between different stakeholders, both clinical and non-clinical, which improves the adoption and effectiveness of these digital tools. This theoretical approach made it possible to design a more holistic intervention, addressing not only medical but also motivational and educational aspects.

In addition, recent studies have highlighted the value of incorporating diverse functionalities to enhance patient engagement and clinical outcomes. For instance, mobile applications for hypertension management that integrate educational modules, blood pressure monitoring, and lifestyle modification support have been shown to improve both self-efficacy and treatment adherence [9]. Applications designed for type 2 diabetes management have also shown promising results when incorporating functionalities such as glucose monitoring, insulin dose suggestions, and patient education modules, which improve glycemic control and promote healthier behaviors [6]. Moreover, studies identifying key features of self-care applications highlight the importance of integrating personalized feedback, goal setting, and activity tracking to optimize user engagement and health outcomes [7]. This underscores the importance of combining educational content with interactive features that support continuous self-management.

However, despite these advances, some mobile health interventions

Table 1
Summary of results.

Author (year) Country	Type of Study	Pathology	Target	APP Design	Results	Quality Jadad/ MINORS
Alharbey et al. (2019) USA.	Quasi-experimental	COPD	Design an innovative mobile health (mHealth) application system called "MyLung" that provides comprehensive solutions to increase self-awareness and promote better self-care management.	It consists of two cycles: 1. Prototype design cycle: • Problem: Lack of access to information and educational empowerment for COPD patients. • Literature review: Identification of meta-requirements based on four domains: access to information, educational empowerment, chronic disease management, and mobile health. • Preliminary design: Use of the Health Belief Model (HBM) and BCSS principles. • Validation: Demonstration session with a COPD specialist and a focus group with technology and health experts. • Adjustments: Review of requirements and feedback to improve the prototype. 2. Final design cycle: • Refinement: Implementation of final features for "MyLung" based on feedback. • Implemented modules: o Educational: Videos and information on COPD. o Risk reduction: Information to avoid risk factors. o Monitoring: Self-monitoring of symptoms and vital signs with integration of medical devices.	Sample: 21 Quantitative analysis: • Follow-up: Four qualitative follow-up interviews. • Quantitative results: o Level of consciousness: - Before vs. after using the app: Mean 3.28 vs. 4.56; $t(10) = 6.062$; $P < 0.001$. - Intervention vs. control: Mean 4.56 vs. 3.31; $t(19) = 4.80$; $P < 0.001$. o Self-efficacy: - Before vs. after using the app: Mean 3.11 vs. 5.56; $t(10) = 2.96$; $P = 0.01$. - Intervention vs. control: Mean 5.56 vs. 3.66; $t(19) = 2.8$; $P < 0.01$. o Behavioral intention: - Before vs. after using the app: Mean 2.91 vs. 4.55; $t(10) = 3.212$; $P = 0.009$. Integration: • Findings from quantitative and qualitative studies show the comprehensive impact of MyLung design on COPD patients	19
Breckneret al **(2022) Germany**	RCT and observational	Chronic diseases	To examine the effects of TelePraCMan on patient activation and quality of life, and we explored the underlying contextual factors, impacts, and degree of implementation.	Primary care physicians, physician practice assistants with additional training, and patients participated in the development of TelePraCMan through focus groups, interviews, and questionnaires.	Participants: 27 No statistically significant differences were found between the two groups in quality of life.	2
Masadeh et al. (2023) Jordan	Quasi-experimental	DM	To evaluate the effect of a diabetes self-management mobile application on self-efficacy, self-care agency, and self-care management among 128 Jordanian patients with Type 1 Diabetes Mellitus.	The educational content was obtained from a specialized diabetes center and validated by two experts in diabetes mellitus (DM). Each subheading was evaluated on a scale of 1 (not relevant) to 4 (very relevant). The calculated Relevance Index was 1.00 (range 0–1), indicating a high relevance of the validated content according to currently used tools.	Independent samples *t*-test: • There were no significant improvements in self-efficacy (SE), self-care agency (SCA), and self-care management (SCM) in the control group (CG) compared to baseline levels. • Intervention group (IG): Significant improvements in SE after using the app ($t(63) = -2.826$, $p = 0.006$). • SCA in GI showed no significant differences between pre-and post-test. ANCOVA: • SCM: Significant difference between CG and IG after controlling for SE and SCA ($F(1, 124) = 4.366$, $p = 0.039$; $\eta^2 = 0.034$). • SE explained 26.3 % of the variance in SCM. Repeated Measures ANCOVA: • Significant difference in SCM in GI between pretest and posttest ($F(1, 61) = 5.257$, $p = 0.025$; 7.9 % variance explained by app). • The covariation of SE and ACS was not significant.	19

(*continued on next page*)

Table 1 (*continued*)

Author (year) Country	Type of Study	Pathology	Target	APP Design	Results	Quality Jadad/ MINORS
R Buis et al. (2024) USA	ECA	HTA	To determine the effect of MI-BP on BP, physical activity, sodium intake, medication adherence, and BP control compared with improved usual care control at 1-year follow-up.	The MI-BP intervention was developed by a research group based on their previous work with the BPMED text messaging intervention to improve adherence to HTA medication in the same population.	Participants: 162. Decrease in systolic BP (1 year): • MI-PA group: −22.5 mm Hg ($P < 0.001$). • Control group: −24.1 mm Hg ($P < 0.001$). • Time/arm interaction: Not significant ($P = 0.99$). Other Results: Similar improvements in diastolic BP, physical activity, sodium intake, medication adherence, and BP control; no significant differences between groups. Dropout rate: Approximately 60 % in both groups.	2
Sittig et al. (2020) USA	ECA	DM	To determine the impact of a mHealth application that incorporated theory-based trigger messages. These messages took different forms following Fogg's behavioral model (FBM) and focused on self-efficacy, knowledge, and self-care.	The focus groups were conducted as follows: • Participants: o Clinical experts: 1 endocrinologist, 1 nurse practitioner, 2 registered nurses, 3 dietitians (2 diabetes educators). o Patients: 9 participants with type 2 diabetes, representative of the target population. • Duration: 1.5 h each session. • Key results: o Areas identified: Diet, exercise, and self-management. o Application: These areas became the educational modules of capABILITY: - Module 1: Diet. - Module 2: Exercise. - Module 3: Self-management	Participants: 20 enrolled (12 analyzed); mean age 54.7 years; 75 % female, 75 % white. Significant Improvements: • General diet ($P = 0.03$). • Exercise ($P = 0.005$). • Blood glucose ($P = 0.02$). • High and medium users ($n = 14$): improvements in self-efficacy ($P = 0.008$) and exercise ($P = 0.01$). Commitment: • Average Duration: Control 621s, Spark 537s, Facilitator 500s. • Tasks Completed: Spark with the highest adherence (75.1 %). ANOVA: showed no significant differences, but the spark group responded faster to the messages. Informative meeting: 8 participants; the app helped control DM and motivated them to continue its use. Conclusion: capABILITY significantly improved diet, exercise, and glucose control; the spark group showed faster responses, and users well received the app.	2
Zhang P et al. (2024) China	ECA	DM	The primary objective was to assess whether the intervention improved the achievement of combined blood glucose, BP, and cholesterol targets.	Needs Analysis: • Based on behavior change theories (Michie). • Assessment of capabilities, opportunities, and motivation of medical staff, families, and patients. • Identification of how mHealth can mitigate barriers to diabetes care. Review of Guidelines: • Synthesis of recommendations from Chinese guidelines for preventing and treating type 2 diabetes. User-Centered Design: • Participation of FHP, patients, physicians, and staff in the iterative design of application prototypes.	Participants • Participants Recruited: 2072 (80 clusters: half rural, half urban). • Random Assignment: Intervention group (1038 patients), Control group (1034 patients). • Follow-up (24 months): 1872 patients completed (947 intervention, 925 control). Key Results: • Achieved "ABC" objectives: 35.9 % intervention vs. 29.9 % control (RR 1.20; $p = 0.025$). • HbA1c: −0.33 % in intervention ($p < 0.0001$). • FPG: −0.58 mmol/L in intervention ($p = 0.00025$). • FPG control: RR 1.21 in intervention ($p = 0.019$).	2

(*continued on next page*)

Table 1 (*continued*)

Author (year) Country	Type of Study	Pathology	Target	APP Design	Results	Quality Jadad/ MINORS
					• BP and Lipids: No significant differences. • Quality of Life (EQ-5D): Improvement of 0.02 ($p = 0.0067$). • Peripheral arterial disease: 0.4 % intervention vs. 2.2 % control (RR 0.20; $p = 0.0017$). • Ischemic heart disease: 4.6 % intervention vs. 7.5 % control (RR 0.62; $p = 0.0039$). • Use of lipid-lowering drugs: Increase in intervention (RR 1.72; $p < 0.0001$). • Other Risk Factors and Comorbidities: No significant differences.	

Fig. 2. Risk of bias of review articles
The Cochrane RoB 2.0 tool evaluates seven types of bias: *(1) Selection Bias:* Related to the randomization sequence and allocation concealment. *(2) Performance Bias:* Concerning the masking of participants and staff to prevent influence on the study outcomes. *(3) Detection Bias:* Involving the blinding of outcome assessors to ensure an unbiased assessment of results. *(4) Attrition Bias:* Results from incomplete outcome data can affect the study's validity. *(5) Reporting Bias:* Arises from selective reporting of results, potentially skewing the findings. *(6) Recruitment Bias:* Additional bias that may affect the study's integrity. *(7) Other Biases:* Any other biases that might impact the study's integrity.

Table 2
Risk of bias of quasi-experimental research in review.

	Alharbey 2019	Masadeh 2023
1. A clearly stated aim	2	2
2. Inclusion of consecutive patients	1	1
3. Prospective data collection	2	2
4. Endpoints appropriate to the aim of the study	2	2
5. Unbiased assessment of the study endpoint	1	1
6. Follow-up period appropriate to the aim of the study	2	2
7. Loss to follow-up less than 5 %	1	1
8. Prospective calculation of the study size	1	1
9. An adequate control group	2	2
10. Contemporary groups	2	2
11. Baseline equivalence of groups	1	1
12. Baseline equivalence of groups	2	2

have struggled to achieve long-term adherence due to usability barriers, lack of motivation, and poor integration into patients' daily routines. Breckner et al. [16] found that applications failing to consider user engagement strategies beyond initial adoption had lower long-term impact. Additionally, Alharbey et al. [18] pointed out that the absence of real-time adaptation and automated recommendations in some applications reduced their clinical effectiveness. Mehraeen et al. [8] further highlight that the design and development process of mobile applications for chronic disease management must include iterative user feedback to improve usability and engagement over time. Their findings indicate that incorporating patient preferences into the design phase contributes to better long-term adherence and acceptance of the application.

While these challenges have been identified, the evidence on long-term engagement strategies remains scarce, as few studies have evaluated the sustained impact of mobile health interventions over extended periods. This highlights the need for further research to determine which design features contribute most effectively to maintaining adherence in chronic disease management. This is further supported by Guo et al.[27], who found that mobile eHealth interventions designed to improve patient knowledge and self-care require structured educational components and interactive engagement strategies to maintain adherence.

When comparing these findings to the studies reviewed, it becomes evident that applications incorporating personalized, real-time feedback and adaptive goal-setting strategies are more effective in sustaining long-term user engagement. This is particularly relevant in chronic disease management, where maintaining motivation over time can be challenging. The success of applications integrating behavioral change theories and continuous user feedback [7,8] suggests that these elements are not just complementary but essential for optimizing health outcomes. Moreover, the integration of these functionalities appears to mitigate common barriers to adherence, such as lack of motivation and poor self-efficacy, which are frequently observed in chronic disease populations.

Therefore, the review suggests that the most effective interventions are those that combine a participatory design with ongoing validation, integrating both the perspectives of end users and health professionals. This approach not only ensures the relevance of digital tools but also improves the accuracy and reliability of the information they contain, crucial aspects for their long-term use by patients and professionals.

However, this review also highlights that interventions lacking real-time personalization, adaptive goal setting, or behavioral reinforcement tend to be less effective in sustaining long-term engagement and self-management. Studies such as those by Breckner et al. [16] and Sittig et al. [21] emphasize that incorporating behavioral trigger messages and continuous user motivation can significantly improve adherence and clinical outcomes. Additionally, findings from Zhang et al. [17] indicate that digital health interventions integrating real-time feedback and patient-provider interaction are more successful in optimizing self-management outcomes. Mehraeen et al. (new citation) further reinforce this idea, showing that tailored self-care applications designed with active user involvement lead to better health outcomes and improved adherence compared to generic, non-personalized applications [8]. These insights reinforce the importance of designing applications that not only provide static educational content but also include interactive, personalized support mechanisms to maintain engagement and enhance long-term disease management.

Overall, this review highlights the importance of a user-centered design approach to maximize the effectiveness and adoption of mobile applications in chronic disease management. Furthermore, ensuring that these applications integrate dynamic, behaviorally informed strategies may help bridge common gaps in adherence and engagement.

The incorporation of these tools into existing healthcare systems is essential to facilitate their large-scale implementation, creating a more robust framework for chronic disease management. This, in turn, could contribute to sustained improvements in patient quality of life and greater efficiency in healthcare delivery.

4.1. Principal findings

The review highlighted several critical insights into the development of mobile applications for chronic disease self-management. It was found that employing user-centered design and participatory methods significantly enhances user engagement and improves health outcomes. Successful applications often included features such as educational content, reminders, and symptom monitoring, which were instrumental in maintaining user engagement. The findings emphasize the need for standardized guidelines in app development to ensure clinical validity and usability, thereby promoting greater adoption among healthcare providers and patients.

4.2. Practical implications

The findings of this review have several practical implications for the development and implementation of mobile health applications. Firstly, the integration of participatory design approaches that involve both patients and healthcare professionals from the early stages of development is essential. This strategy ensures that the applications address real-world needs and improve usability. Secondly, the incorporation of adaptive learning features, such as personalized feedback loops and dynamic goal-setting, can enhance long-term engagement, particularly in chronic conditions that require sustained self-management efforts.

Moreover, these insights could inform health policy by emphasizing the need for standardized guidelines on the development and evaluation of health applications. Regulatory bodies could benefit from establishing criteria that ensure the clinical validity, security, and usability of mobile health technologies, fostering greater trust and adoption among both healthcare providers and patients. Lastly, integrating these applications into routine healthcare workflows, supported by appropriate training for healthcare professionals, can optimize their impact, facilitating a more holistic approach to chronic disease management.

4.3. Limitations

There are some limitations, among them, the lack of active user participation in the early stages of development of most of the studies, which could have affected the relevance and usability of the applications.

Another notable limitation is the heterogeneity of the studies included, both in terms of design and populations studied. In addition, most of the applications evaluated have not been subjected to large-scale clinical trials, which limits the generalizability of the results. While many studies have been identified, they are mostly randomized clinical trial protocols that have not yet produced definitive results.

Moreover, the variability in technological platforms and the lack of standardization in the evaluation metrics of mobile health applications complicate the comparison of outcomes across different studies. This inconsistency may hinder the identification of universally effective design elements and functionalities. Additionally, the rapid evolution of mobile health technology presents a challenge in keeping research findings relevant over time, as newer functionalities and user expectations continuously emerge.

Therefore, future research must include studies with larger samples and multicenter approaches, which would allow validation of these findings and ensure the applicability of interventions in different contexts and populations. It is also critical to explore how the various functionalities of apps influence treatment adherence and long-term chronic disease management.

5. Conclusion

This study demonstrates that mobile applications for chronic disease self-management are most effective when developed using a user-centered approach and continuous validation. These tools significantly enhance treatment adherence and facilitate improved communication between patients and healthcare professionals. However, the diversity of studies and the absence of large-scale clinical trials limit the generalizability of these findings. Therefore, further research is essential to validate these results and optimize the integration of these applications into healthcare systems.

Future app development projects should prioritize collaboration among healthcare professionals, APP developers, and patients. This collaborative approach ensures that applications are clinically practical, user-friendly, and tailored to patients' needs. Such collaboration enhances the adoption and effectiveness of these applications in real-world settings, ultimately improving patient outcomes and healthcare efficiency.

CRediT authorship contribution statement

Emma Camino Ortega: Software, Resources. **Ana Baroja Gil de Gómez:** Project administration, Investigation. **Amelia González Gamarra:** Writing – review & editing. **Miguel Angel Cuevas-Budhart:** Methodology. **José Luis García Klepzig:** Supervision, Conceptualization. **Mercedes Gómez del Pulgar García-Madrid:** Data curation.

Ethical statement

This paper's methodological approach exempts it from obtaining additional ethical approval, as it does not involve new participants or generate unpublished data that require specific ethical considerations. Our subsequent review is registered with PROSPERO, which ensures that the review adheres to a predefined protocol—a standard practice that guarantees transparency and methodological quality in research. This registry represents our commitment to the scientific community, allowing us to conduct a rigorous and ethical review following best practices established under PROSPERO registry number **CRD42024571644.**

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Declaration of competing interest

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