Effectiveness of mHealth Interventions for improving eHealth Literacy among Patients with Chronic Diseases: A Meta-analysis and Systematic Review

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Abstract

Background: With widespread use of the Internet and mobile devices, ehealth literacy promotion is critical for chronic disease management. However, the effectiveness of mhealth interventions on eHealth literacy among patients with chronic diseases are still inconclusive.

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Methods: A comprehensive search strategy was developed, and eight electronic databases—PubMed, Web of Science, Embase, Cochrane Library, WanFang Database, China National Knowledge Infrastructure (CNKI), CQVIP, and Chinese Biomedical Literature (CBM)—were systematically searched for studies published up to October 31, 2024. Patients with chronic diseases were included based on predefined inclusion criteria. The Cochrane Effective Practice and Organisation of Care (EPOC) group methods for nonrandomized controlled trials and the Cochrane Collaboration Tool for randomized controlled trials were used to assess the risk of bias. All statistical analyses were performed using Review Manager (version 5.4; Cochrane Informatics & Technology Services) software. Random effects model was applied to evaluate the homogeneity between studies. The outcome was eHealth literacy score. A narrative and quantitative synthesis of the findings was provided where appropriate.

Results: Among 1665 eHealth literacy–related papers, 10 studies (6 randomized controlled trials and 4 quasi-experimental studies) involving 2272 participants were included in this study. The overall findings demonstrated that eHealth literacy interventions significantly improved eHealth literacy efficacy (standardized mean difference=1.00, 95% CI ?0.40 to 1.60; P=0.001), with substantial heterogeneity observed (I^2=93%, P<0.001). Subgroup analyses revealed that interventions delivered via online applets were significantly more effective than face-to-face teaching (standardized mean difference=0.50, 95% CI ?0.11 to 0.88; P<0.001), and interventions grounded in theoretical frameworks were significantly more effective than those without theoretical guidance (standardized mean difference= 1.14, 95% CI ?0.03 to 2.25; P=0.05). Shorter intervention durations (<3months) showed more consistent improvements (standardized mean difference=0.70, 95% CI ?0.07 to 1.32; P=0.03) compared to longer durations interventions. Hospital-based interventions showed greater efficacy (standardized mean

difference= 1.67, 95% CI ?0.08 to 3.26; P=0.04) compared to community-based approaches.

Conclusions: This meta-analysis demonstrates that mHealth interventions significantly improve eHealth literacy among patients with chronic diseases. The most effective approaches are delivered via online applets, grounded in theoretical frameworks, and implemented within hospital settings over shorter durations (<3 months). These findings highlight the potential of targeted mHealth strategies to enhance patients' ability to access, understand, and utilize digital health information, thereby supporting chronic disease self-management. Clinical Trial: PROSPERO International Prospective Register of Systematic ReviewsCRD42024622807; https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024622807

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Conclusions: This meta-analysis demonstrates that mHealth interventions significantly improve eHealth literacy among patients with chronic diseases. The most effective approaches are delivered via online applets, grounded in theoretical frameworks, and implemented within hospital settings over shorter durations (<3 months). These findings highlight the potential of targeted mHealth strategies to enhance patients' ability to access, understand, and utilize digital health information, thereby supporting chronic disease self-management.

Trial Registration: PROSPERO International Prospective Register of Systematic ReviewsCRD42024622807; https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024622807

Introduction

Chronic diseases which threaten the full-life-cycle health of populations, particularly older adults, have become the global challenges for the public health among worldwide. According to the World Health Organization (WHO), chronic diseases, including cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes lead to approximately 41 million deaths globally each year, accounting for 74% of all all-cause deaths[1], with type 2 diabetes, cardiovascular diseases, cancers, and respiratory diseases accounting for 80% of premature deaths[2]. Moreover, factors such as population aging, lifestyle changes such as smoking, physical inactivity and environmental pollution exacerbate the incidence of chronic diseases[3]. To address the rising prevalence of chronic diseases, effective strategies for chronic diseases management are urgently needed.

eHealth literacy is defined as the ability of individuals to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem[4]. Studies reported that enhanced eHealth literacy empowers patients to leverage online resources, telemedicine, and mobile health applications, thereby promoting treatment adherence and health outcomes[5]. Several studies showed ehealth literacy was not insufficient among patients with chronic diseases. Wang *et al* reported that only 5% of hospitalized stroke patients in tertiary hospitals achieved adequate health literacy[6]. Similarly, Kamali *et al* reported that only 38.5% of patients with type 2 diabetes mellitus (T2DM) had adequate eHealth literacy, with 61.5% exhibiting low literacy[7]. Moreover, studies reported that inadequate health literacy among patients with chronic diseases were associated with increased mortality and readmission rates[8, 9], decreased quality of life[10] and increased disease-related healthcare costs[11].Fabbri found that low health literacy was significantly associated with increased mortality (HR = 1.91, 95% CI: 1.38~2.65) and hospitalization rates (HR = 1.30, 95% CI: 1.02~1.66) in patients with heart failure[12]. Similarly, Tekin and Kilic reported that chronic disease patients with inadequate ehealth literacy exhibited poorer attitudes toward cancer screening (β= 0.563, $p < 0.05$), with only 20% aware of screening programs and 36.3% having undergone screening[13]. Studies collectively underscore that inadequate health literacy impedes self-management and preventive care adherence in chronic disease populations [14, 15]. Despite the potential of digital tools, many patients exhibit low eHealth literacy, limiting their capacity to effectively navigate and utilize these technologies. Consequently, improving chronic patients' eHealth literacy is an immediate need [16]. Patients with higher eHealth literacy are more adept at utilizing online platforms, mobile applications, and telemedicine to access personalized information, optimizing medication adherence, symptom monitoring, and lifestyle adjustments[17, 18]. Enhanced eHealth literacy also improves health decision-making, reduces treatment delays, and mitigates unhealthy behaviors stemming from misinformation.

Mobile health (mHealth) is defined as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices”[19]. Mobile health interventions offer a promising strategy to boost eHealth literacy, leveraging their accessibility and potential for personalized chronic patients engagement. Bo Xie[20] conducted a study to improve the e-health literacy of older adults through computer training using NIH online resources. The intervention significantly enhanced participants' computer and web knowledge, reduced anxiety, and increased their ability to seek and use health information. The results indicate that targeted training can effectively empower older adults to better manage their health.Likewise. Likewise, Banbury et al[21] conducted the Telehealth Literacy Project, a study that co-designed and evaluated a telehealth intervention for older adults with chronic diseases. The intervention aimed to improve health literacy and self-management skills through group videoconferencing. Results showed improvements in health literacy behaviors and self-management skills, with participants also reporting enhanced social support and engagement.. However, despite the potential of mHealth tools to improve eHealth literacy and health outcomes, few studies has examined the effectiveness of mHealth-based interventions on enhancing eHealth

literacy among patients with chronic diseases. Although many researchers have explored strategies to improve eHealth literacy among patients with chronic diseases, existing studies remain limited by heterogeneous methodologies, inconsistent outcomes, and a lack of theoretical grounding[22, 23]. Hence, there is a urgently need for rigorous, standardized approaches to evaluate the effectiveness of eHealth literacy interventions and optimize the existing eHealth literacy interventions for patients with chronic diseases.

Therefore, we conducted this study to assess the effectiveness of mhealth interventions on eHealth literacy among patients with chronic disease systematically. Our findings will provide solid evidence for designing of targeted, scalable mhealth strategies.

Methods

Overview

This study was rigorously conducted in accordance with the methodological guidelines established by the Cochrane Collaboration[24] and the reporting standards outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 statement[25] (**Supplementary 1**). The study protocol was registered with PROSPERO (CRD42024622807) .

Search Strategy

Two researchers independently conducted a thorough search of the all relevant studies published in the following databases: PubMed, EMBASE, Web of Science, Cochrane Library, WanFang Database, China National Knowledge Infrastructure (CNKI), CQVIP, and Chinese Biomedical Literature (CBM). The end of the retrieval date was set as November 31, 2024. MeSH terms and free words were used in combination to search the relevant studies. In addition, the language of the studies was set as English and Chinese. The references of pertinent previous systematic reviews were also screened as supplementary sources. The full search strategies were show in Table S1 to S8.

The following is an illustration of a search strategy applied to the PubMed database:
#8= #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7
#10= #8 OR #9
#13= #10 AND #11 AND #12
Search: (((((((("Chronic Disease"[Mesh]) OR ("Diabetes Mellitus"[Mesh])) OR ("Hypertension"[Mesh])) OR ("Coronary Disease"[Mesh])) OR ("Lung Diseases"[Mesh])) OR ("Pulmonary Disease, Chronic Obstructive"[Mesh])) OR ("Liver Diseases"[Mesh])) OR ((((((((((((((((chronic disease[Title/Abstract]) OR (Chronic Illness[Title/Abstract])) OR (Chronic Illnesses[Title/Abstract])) OR (Diabetes Mellitus[Title/Abstract])) OR (high blood sugar[Title/Abstract])) OR (high blood glucose[Title/Abstract])) OR (diabetes*[Title/Abstract])) OR (hyperglycemia[Title/Abstract])) OR (high blood pressure[Title/Abstract])) OR (high pressure[Title/Abstract])) OR (coronary heart disease*[Title/Abstract])) OR (Disease, Coronary Heart[Title/Abstract])) OR (Heart disease *[Title/Abstract])) OR (Coronary[Title/Abstract])) OR (obstructive pulmonary disease[Title/Abstract])) OR (COPD[Title/Abstract])) OR (Liver disease *[Title/Abstract]))) AND ((((((((((eHealth literacy[Title/Abstract]) OR (Computer Literacy[Title/Abstract])) OR (m-health literacy[Title/Abstract])) OR (Computer Literacies[Title/Abstract])) OR (Literacies, Computer[Title/Abstract])) OR (eHealth literacy[Title/Abstract])) OR (digital literacy[Title/Abstract])) OR (digital health literacy[Title/Abstract])) OR (mhealth literacy[Title/Abstract])) OR (telehealth literacy[Title/Abstract])))) AND ((intervention*) OR (influence)) .

Selection Criteria

Eligibility criteria were set based on the PICOS framework (populations, interventions, comparisons, outcomes, and study design): (1) Population: People with chronic illnesses (diabetes, high blood pressure, heart disease, lung disease, kidney disease, cancer, stroke, or any combination of these

conditions that meet the diagnostic criteria for clinical diseases). (2) Interventions: mHealth-based interventions aimed at improving eHealth literacy in chronic disease patients. Eligible interventions included: ①Mobile health applications (e.g., disease management apps, medication reminders); ②SMS/text message-based health education; ③Telehealth consultations via mobile devices; ④ Interactive mobile learning modules;⑤ Wearable device-integrated education programs. All interventions required primary delivery through mobile platforms (smartphones/tablets) with at least one eHealth literacy outcome measure.
(3) Control: The study subjects in control group received either no intervention at all, conventional interventions (e.g., health education or general nursing practices).
(4) outcome: eHealth Literacy Score.
(5) Research design: Randomized controlled trials and quasi-experimental studies were included in this systematic review and meta-analysis. In the former, the experimental group receives mhealth Intervention, while the latter group either receives no intervention or traditional interventions (mostly written or spoken health education materials). Non-experiment trials, review or discussion papers, non-Chinese and non-English papers, studies with no full text available, and studies with inadequate data were excluded.

Study selection
A thorough screening procedure was conducted in compliance with PRISMA 2020and two reviewers (Xueqin Y and Yueting W) screened the included studies independently. All collected studies were first imported into EndNote X9. Then, studies that were eliminated according to the inclusion and exclusion criteria by reading titles and abstracts. Finally, studies were screened strictly by reading the full-text. Discussions or negotiations with a third reviewer (Xingyu L) were used to settle disagreements.

Data Extraction
Yang XQ and Mang YP extracted data from each study separately. Study authors, publication date, country, population (population and sample size), study design (description of numerical interventions, characteristics of intervention groups, and duration), theoretical framework, intervention site outcome indicators (measurement tools), and important study outcomes were extracted. The author team engaged in discussions and reexamined the original study in cases where there were disagreements over data extraction until an agreement was reached.

Quality Evaluation
The Cochrane Handbook was used as the Systematic Reviews of Interventions' risk-of-bias tool for randomized trials (version 5.1.0) and two reviewers (Yang XQ and Wang YT) assessed the included studies' methodological quality and risk of bias independently. Six domains are included in the tool: attrition bias (incomplete outcome data), performance bias (blinding of personnel and participants), detection bias (blinding of outcome assessment), selection bias (hidden allocation and random sequence generation), reporting bias (selective reporting), and other bias (anything else, ideally prespecified). The following nine criteria were followed to evaluate the possible bias of included studies in non-randomized controlled trials in accordance with the EPOC Cochrane Systematic Review Group Risk of Bias criteria [26]: (1) Did the allocation sequence generate sufficiently? (2) Do allocations have enough concealment? (3) Were the measures of baseline outcomes comparable? (4) Are baseline traits comparable? 5) Did insufficient outcome data receive enough attention? (6) During the study period, was awareness of the allocation intervention sufficiently prevented? (7) Is there sufficient contamination protection for the study? (8) Were there no reports of selective outcomes? (9) Is there no additional chance of prejudice? There are three grades for each domain: unclear risk of bias, high risk of bias, and low risk of bias. Xingyu L was consulted and discussions were held with her in order to settle disagreements.
Statistical analysis

For the continuous outcome of eHealth literacy, we used the 95% confidence interval (CI) and standardized mean difference (SMD) to represent effect size.. The heterogeneity of study outcomes was assessed using I^2, and I^2 75% was considered as considerable heterogeneity. Therefore, in this study, a random effects model was chosen to analyze the data due to the high degree of heterogeneity among the included studies. All statistical analyses were performed using Review Manager (version 5.4; Cochrane Collaboration) and statistically significance was set as P 0.05.

Results

Selection of the Studies

The screening precedure for the subsequent sub-phases (title/abstract screening, full text assessment) was strictly followed the PRISMA framework to ensure transparency and reproducibility. Initially, 1665 articles were searched, including 699 from PubMed, 192 from Embase, and 203 from Web of Science. Using EndNote software, 468 copies were initially removed from the Cochrane Library (n=314), the WanFang Database (n=37), the CBM (n=84), the CQVIP (n=28), and the CNKI (n=108). Following title and abstract screening of 1,197 papers, 1,149 were excluded for not meeting the inclusion criteria or lacking relevance to the study topic.. The full version of the remaining 48 studies were read and 43 of them were excluded for the following reasons: non-experimental studies (n=12); full-text was not available (n=9); mismatched study populations (n=10); and insufficient data (n=9). Following a comprehensive manual search, two studies were excluded due to irrelevance to the research objectives based on preliminary screening. Additionally, three duplicate publications were identified and removed to ensure data uniqueness. During full-text evaluation, one study was excluded as the complete manuscript was unavailable despite exhaustive retrieval efforts. The final analysis included ten eligible studies, comprising seven for quantitative synthesis and three for qualitative thematic analysis. Figure 1 showed the comprehensive flowchart of the literature search process.

Characteristics of the Studies

10 clinical studies (4 quasi-experimental studies[27-30]and 6 randomized controlled trials[31-36]) were reviewed and 2,272 participants with various chronic conditions were included. Geographically, the studies were predominantly conducted in China[27-29, 31, 33](n=5), Australia[34, 35](n=2), Canada[36](n=1), Denmark[30](n=1) and the United States[32] (n=1). All studies were published between 2016 and 2024. Two of the papers were published in Chinese, while eight were published in English. The interventions primarily targeted the promotion on eHealth literacy, with the majority (n=8) utilizing mHealth platforms including mobile applications and web-based portals, while the remaining studies (n=2) adopted hybrid or offline intervention approaches. Notably, three studies were guided by theoretical frameworks, whereas the other studies were designed with pragmatic intervention. The intervention durations ranged from short-term (1-12 weeks) to long-term (3-12 months). The key features of the ten studies were displayed in Table 1.

Risk of Bias in Studies

For the six randomized[31-36] controlled trials in this study, the Cochrane Risk of Bias Assessment Tool was used to evaluate the included studies' risk of bias. All studies described randomized design, and one of them went into great detail about how randomized sequences was generated and how allocation concealment works. Figure 2a demonstrated risk of bias of the six randomized controlled trials. The risk of bias four non-RCTs[20-23] were assessed using Review Manager 5.4 and summarized in Figure 2b. These studies exhibited high/unclear risk of bias in sequence generation and allocation concealment due to their non-randomized design. In the two pre-post studies[29, 30], absence of baseline group comparison introduced high risk of selection bias, consequently affecting both baseline characteristics and outcome measures.

Overall Effectiveness of MHealth Interventions on Ehealth Literacy in Patients with Chronic Diseases

The effectiveness of eHealth Literacy interventions in patients with chronic illnesses was systematically assessed in this review. As explained below, specific data could be found in Table S10. Seven of the included studies underwent meta-analysis, and all of them reported improvements in eHealth literacy. Health literacy efficacy is significantly improved by mhealth interventions (SMD=1.00, 95% CI −0.40 to 1.60; *P*=0.001). We found that the type of intervention used in the data, whether theoretical framework was adopted or not, the length of the intervention, and the location of the intervention could all contribute to a significant degree of heterogeneity (*P*<0.001, I^2=93%，as shown in Figure 3).

Analysis of Subgroups

We conducted subgroup analysis based on previously identified subgroups, including intervention method, whether the intervention was based on theoretical framework, duration of intervention, implementation setting, and intervention on different chronic diseases, as explained below, in order to investigate evaluate the effectiveness of mHealth intervention on eHealth literacy more specific.

The Effect of mhealth Intervention on eHealth Literacy Varied by Duration of Intervention

Shorter intervention (<3 months) demonstrated statistically significant improvements in eHealth literacy (SMD=0.70, 95% CI −0.07 to 1.32; *P*=0.03), while longer mhealth interventions (≥3 months) did not (SMD=1.52, 95% CI −0.07 to 3.12; *P*=0.06). Heterogeneity was high in both subgroups (≥3 months: I^2=97%, *P*<0.001; <3 months: I^2 =88%, *P*<0.001), with no subgroup differences *P*=0.342). The overall effect was significant (SMD=1.00, 95% CI −0.40 to 1.60; *P*=0.001), as shown in Figure 4.

Effectiveness of mhealth Intervention with or without Theoretical Frameworks on Enhancing eHealth Literacy

We systematically evaluated the efficacy of mhealth interventions in relation to their theoretical underpinnings. Theoretically guided interventions demonstrated marginally greater effectiveness in improving eHealth literacy (SMD= 1.14, 95% CI −0.03 to 2.25; *P*=0.05) compared to non-theoretically guided interventions (SMD=0.89, 95% CI −0.13 to 1.56; *P*=0.02). High heterogeneity was observed in both subgroups (theoretically guided: I^2=95%, *P*<0.001; non-theoretically guided: I^2=90%, *P*=0.001), with no significant subgroup differences (I^2=93%, *P*=0.71). The overall effect remained significant (SMD=1.00, 95% CI −0.40 to 1.60; *P*=0.001, as shown in Figure 5).

Effectiveness of mhealth Interventions via Online Application versus Face-to-Face in Enhancing eHealth Literacy

We found that interventions delivered via online application significantly improved eHealth literacy effectiveness (SMD=0.50, 95% CI −0.11 to 0.88; *P*< 0.001), whereas face-to-face interventions showed no statistically significant effect (SMD=2.46, 95% CI −0.16 to 5.07; *P*=0.07). Substantial heterogeneity was observed in both subgroups (online applets: I^2 = 80%, *P*<0.001; face-to-face: I^2 = 96%, *P*<0.001), with subgroup differences (I^2 =52.8%, *P*=0.15). The overall effect favored eHealth literacy interventions (SMD=1.00, 95% CI −0.40 to 1.60; *P*=0.001, as shown in Figure 6).

Effectiveness of mhealth Intervention Settings on eHealth Literacy Improvement

Hospital-based interventions showed a more favorable impact on eHealth literacy (SMD=1.67, 95% CI −0.08 to 3.26; *P*=0.04), whereas community-based interventions did not reach statistical significance (SMD=0.30, 95% CI −0.00 to 0.61; *P*=0.05). Heterogeneity was substantial in hospital settings (I^2 = 97%, *P*<0.001) but moderate in community settings (I^2=39%, *P*<0.001). Subgroup differences were notable (I^2=63.6%, *P*=0.10), and the overall effect remained positive (SMD=0.94, 95% CI −0.29 to 1.59; *P*=0.004, as shown in Figure 7).

Sensitivity Analyses

To identify heterogeneity of potential sources in health literacy outcomes, we conducted sensitivity

analyses by sequentially excluding individual studies and examining forest plots. The exclusion of two dissertations (due to methodological heterogeneity in study design) contributed to reduced statistical heterogeneity (I^2 = 19%), while the overall effect remained statistically significant (SMD = 0.31, 95% CI: −0.12 to 0.74; P = 0.001). These results suggested that study design differences contributed significantly to the observed heterogeneity in the primary analysis. The refined effect estimates were presented in Figure 8.

Discussion

Principal Findings

This systematic review and meta-analysis evaluated the effectiveness of mHealth interventions in enhancing eHealth literacy among patients with chronic diseases. The analyzed mHealth interventions were primarily delivered via applications (8/10 studies), which aligned with their prevalent utilization in Chinese healthcare settings. Other mHealth platforms were excluded from the analysis owing to heterogeneous outcome reporting (e.g., varying measurement tools or metrics) or inadequate assessment of eHealth literacy levels. The results demonstrated that these interventions significantly improved eHealth literacy (SMD=1.00, 95% CI −0.40 to 1.60; P=0.001). Further analyses revealed that interventions delivered via online applets were significantly more effective than face-to-face teaching in improving eHealth literacy among chronic disease patients (SMD=0.50 vs SMD=2.46; P<0.001). Similarly, interventions grounded in theoretical frameworks were marginally more effective than those without theoretical guidance (SMD=1.14 vs SMD=0.89; P=0.05). Shorter intervention durations (<3 months) showed more statistically significant improvements (SMD=0.70, 95% CI −0.07 to 1.32; P=0.03), and hospital-based interventions were more effective than community-based approaches (SMD=1.67, 95% CI −0.08 to 3.26; P=0.04). These findings highlighted the potential of eHealth literacy interventions through mHealth to enhance chronic disease management.

Effectiveness of mHealth Interventions

Evidence indicates a 3-month critical window for optimal eHealth literacy skill gains. Beyond this, effectiveness plateaus and dropout rises. The 3-month limit ensures interventions end during peak effectiveness and engagement.[37, 38] , we categorized interventions by duration (short-term: <3 months; longer-term: ≥3 months). Our findings demonstrated that shorter interventions (<3 months) significantly improved eHealth literacy (SMD=0.70, P=0.03), whereas longer interventions (≥3 months) showed a larger point estimate that did not reach statistical significance (SMD=1.52, P=0.06). This aligned partially with meta-analyses on eHealth literacy interventions where peer-led training significantly improved patient activation measures (PAM) and Perceived Involvement in Care Scales (PICS) at 12 months. However, the non-significant result for longer interventions in our study diverges from such findings. This discrepancy may stem from challenges in sustaining engagement and adherence among patients with chronic diseases in self-directed health interventions, particularly beyond 8–12 weeks when digital fatigue escalates and dropout rates rise substantially [39]. Future research should prioritize determining optimal intervention duration by integrating chronic disease management frameworks.

A comparative analysis was conducted to examine whether theory-guided mHealth interventions demonstrated superior effectiveness in improving eHealth literacy compared to non-theory-based approaches. both types of interventions showed improvements in eHealth literacy efficacy, with theoretically guided interventions yielding a slightly higher effect size compared to non-theoretically guided interventions. This suggests that interventions grounded in established theoretical frameworks may provide a more structured and evidence-based approach, potentially leading to better outcomes[40]. Theoretical guidance could help ensure that interventions are tailored to address specific behavioral or cognitive factors that influence eHealth literacy, such as self-efficacy or health beliefs, consistent with the findings of a previous study of eHealth literacy among older adults based on theoretical guidance[41]. However, the significant heterogeneity within both subgroups indicated

that the presence of theoretical guidance alone was not sufficient to guarantee effectiveness. Our findings suggested three essential moderators of effectiveness: (a) the methodological rigor of the theoretical framework, (b) its cultural congruence with the target population's health beliefs and digital literacy levels, and (c) the intervention's implementation fidelity. These factors collectively explain the significant heterogeneity observed across studies (I^2=97%). Future studies should focus on identifying which theoretical models are most effective for specific chronic disease populations and how they can be optimally applied in eHealth literacy interventions.

Our meta-analysis demonstrated that online interventions significantly enhanced eHealth literacy (SMD=0.50, 95% CI −0.11 to 0.88; *P*<0.001). In contrast, face-to-face modalities showed a clinically substantial effect size that was statistically non-significant (SMD=2.46, 95% CI −0.16 to 5.07; *P*=0.07). The significant benefit observed for online approaches aligns with findings from a previous review [42], which indicated that computer-based applications are a widely utilized and effective modality for eHealth literacy interventions. However, a p revious study also found that face-to-face interventions were more effective for psychological interventions[43]. Several reasons were account for this. First, extreme heterogeneity in face-to-face interventions (I^2=96%, *P*<0.001) indicates variable implementation fidelity (facilitator expertise, attendance adherence) that diluted statistical significance despite large effect sizes. Second, logistical barriers (scheduling conflicts, resource limitations) disproportionately constrain in-person delivery, attenuating measurable impacts. Third, standardized eHealth literacy scales may lack sensitivity to nuanced skill gains from interpersonal interactions. The overall positive effect (SMD=1.00, *P*=0.001) confirms the value of interventions but underscores that success depends more on design rigor and contextual adaptation than on delivery modality.

When comparing interventions delivered in hospital versus community settings, hospital-based interventions showed a more favorable impact on eHealth literacy efficacy, while community-based interventions did not reach statistical significance. This difference might be attributed to the more controlled and well-equipped environment of hospitals, which facilitated the implementation of structured and intensive interventions. Additionally, hospital-based interventions may benefit from the involvement of healthcare professionals who can provide immediate feedback and support, enhancing the learning experience. However, the significant heterogeneity in both subgroups suggests that the effectiveness of interventions may also depend on the specific characteristics of the hospital or community setting, such as the availability of resources, the level of patient engagement, and the integration of the intervention into routine care.

Limitations

Three major limitations of this study should be mentioned. First, the restriction to English and Chinese language publications may introduce selection bias and limit the cross-cultural applicability of our findings. Second, substantial methodological heterogeneity was observed across included studies, particularly in intervention protocols and outcome measurement approaches, potentially compromising the robustness of our meta-analytic results. Third, the modest sample size (10 studies involving 2,272 participants) and predominant focus on developed healthcare systems may constrain the external validity of our conclusions. These limitations highlight the need for future multinational studies employing standardized methodologies to strengthen the evidence base in this field.

Conclusions

This meta-analysis confirms that mHealth interventions effectively enhance eHealth literacy among chronic disease patients. The most impactful approaches utilize online applets rather than face-to-face methods, integrate established theoretical frameworks, maintain intervention durations under three months, and are implemented in hospital settings. These optimized strategies collectively empower patients to navigate, comprehend, and apply digital health resources more proficiently. Our findings provide actionable evidence for designing scalable mHealth programs to strengthen chronic disease self-management and improve long-term health outcomes.

Conflict of Interests

The authors declare no conflicts of interest.

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Author contributions
YNZ and XQY conceptualized the study. QX, YTW, and XYL developed the methodology. XQY and YTW performed formal analysis. XQY, YTW, MTL, and FHY conducted the investigation. XQY and YTW managed data curation. YXQ wrote the original draft. YNZ, YPM, YXM, and FHY contributed to writing review and editing. YNZ provided supervision and acquired funding. All authors reviewed and approved the final manuscript.

References

Figure Legends

Figure1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram: papers included and excluded in this review.

Figure 2. Risk of bias summary in randomized controlled trials .
a. Risk of bias summary in randomized controlled trials
b. b Risk of bias summary in nonrandomized controlled trials

Figure 3.Effectiveness of mHealth Interventions on eHealth Literacy in Patients with Chronic Diseases IV= inverse variance. Std=standardized.

Figure 4. The effect of mhealth intervention on eHealth literacy varied by duration of intervention .(group 1: duration ≥3 months; group2: duration <3months). IV= inverse variance; Std= standardized.

Figure 5. Effectiveness of with or without theoretical frameworks in enhancing intervention (group1: theoretically guided interventions; group2: no theoretically guided interventions. IV=inverse variance; Std= standardized.

Figure 6. Effectiveness of Interventions via Online application versus Face-to-Face in Enhancing eHealth Literacy
(group1: online applet use; group2: face-to-face teaching). IV=inverse variance; Std=standardized

Figure 7.Effectiveness of Intervention Settings on eHealth Literacy Improvement
(group1: hospital; group2: community). IV=inverse variance; Std=standardized.

Figure 8. Effects of eHealth on 2 dissertations were removed. SMD=standardized mean difference.

Supplementary Files