Review Article

A scoping review of implementation determinants and strategy alignment patterns in mHealth interventions for stroke recurrence prevention between low and high resource settings

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Background: Stroke remains a major global health burden, with high recurrence rates despite preventability through standardized interventions. Mobile health (mHealth) interventions show promise in stroke recurrence prevention, yet mHealth implementation varies significantly across different resource settings. This study aimed to investigate implementation determinants and strategy alignment patterns in mHealth interventions for recurrent stroke prevention between low and high resource settings.

Methods: Six databases [PubMed, Web of Science, Cochrane Library, Scopus, CNKI (China National Knowledge Infrastructure), and Wanfangdata] were searched for the publication period from January 2013 to December 2023. We included empirical studies and evidence syntheses of mHealth interventions for secondary stroke prevention with implementation descriptions, excluding those using specialized medical devices, robot-assisted interventions, or involving participants with significant comorbidities. Implementation determinants were coded using the Consolidated Framework for Implementation Research (CFIR) constructs, and implementation strategies were mapped using Expert Recommendations for Implementing Change (ERIC) taxonomy. Strategy-barrier alignment was summarized by comparing implemented versus expert-recommended strategies across settings. Statistical significance was assessed using non-parametric tests and bootstrap analyses, with sensitivity analyses accounting for study quality.

Results: Fifty-five studies were included, with 52.7% conducted in low resource settings. 74.5% were published between 2019–2023, with randomized controlled trials (RCTs) being the most common study design (49.1%). Interventions primarily utilized smartphone applications (APPs) (49.1%) and instant messaging systems (IMS) (25.5%). Key CFIR determinants differed between resource settings. "Relative Advantage" (9/29 *vs.* 4/23) and "Access to knowledge & information" (11/29 *vs.* 5/23) were emphasized in low resource settings, while "Design Quality & Packaging" (2/29 *vs.* 9/23) and "Reflecting & Evaluating" (1/29 *vs.* 6/23) were highlighted in high resource settings. There was a higher adoption of recommended strategies in low resource settings compared to high resource settings (9.40 *vs.* 7.16 matches per study) as well as more gaps in reported strategies (9.53 *vs.* 8.00 gaps per study). Mann-Whitney U tests showed marginally significant differences in strategy adoption, with bootstrap analysis confirming it [mean difference =2.20, 95% confidence interval (CI): 0.36–4.12]. Implementation gaps showed no significant difference between settings (P=0.34).

Conclusions: Implementation determinants and strategy adoption vary between low and high resource settings. Low-resource settings demonstrate significantly greater adoption of ERIC strategies. Context-

tailored policies are critical to bridge know-do gaps in implementing stroke prevention intervention globally.

Keywords: Mobile health (mHealth); secondary stroke prevention; implementation science; Consolidated Framework for Implementation Research-Expert Recommendations for Implementing Change framework (CFIR-ERIC framework); low and high resource settings

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Introduction

Background

Stroke ranks as the primary contributor to death and disability worldwide, regardless of resource settings (1), with recurrence further elevating the risks of adverse health outcomes (2-4). While stroke is largely preventable through standardized treatment and risk factor control (1,5,6), real-world implementation of evidence-based prevention strategies remains suboptimal, particularly in resource-limited settings.

The suboptimal implementation of intervention strategies manifests in two critical areas. First, clinical practice guidelines, despite their proven effectiveness, often encounter limited active dissemination and low implementation rates in routine care (7,8). Second, ensuring patient adherence to recommended post-discharge regimens presents persistent challenges, especially in maintaining long-term lifestyle modifications and medication compliance (9,10). These gaps in initiating timely intervention and maintaining self-care measures increase risk of recurrent events (11-13) which carry substantially higher mortality rates and worse outcomes.

Mobile health (mHealth) interventions have emerged as a promising solution to address these implementation challenges (14,15). mHealth offers several advantages for stroke prevention utilizing widespread mobile phone penetration: it enables real-time patient-provider interaction and timely feedback (16,17), facilitates early risk identification and symptom management (18,19), and supports sustained patient engagement in self-management (20). Systematic evidence confirms that mHealth interventions enable effective self-management support for stroke survivors through pharmaceutical interventions, public health services and social measures supported by mobile devices with relative high acceptance (21), offering a lightweight (1,22), cost-effective alternative to traditional care, particularly suited for resource-limited settings (23,24).

Rationale and knowledge gap

Recent empirical studies demonstrate varying success in translating mHealth interventions into practice. Trials (25-28) have shown improved clinical outcomes in low resource settings, meta-analyses (16,29) and reviews (30,31) confirmed effectiveness in chronic disease management, yet translating this potential into sustainable implementation

Highlight box

Key findings

- Implementation determinants and strategy adoption patterns differ systematically between low and high resource settings in mHealth interventions for stroke prevention.
- Resource-limited countries demonstrate higher adoption of recommended implementation strategies, although there are gaps in the report strategies based on Expert Recommendations for Implementing Change (ERIC) mapping.
- Core implementation strategies like readiness assessment, knowledge sharing, leadership and stakeholder engagement are universally endorsed but executed differently across contexts.

What is known and what is new?

- mHealth interventions are effective for stroke prevention across healthcare settings. Implementation barriers vary between resource-rich and resource-limited contexts.
- To our knowledge, this the first study to quantitatively analyze implementation determinants and strategy-barrier alignment patterns using Consolidated Framework for Implementation Research-ERIC framework across resource settings.
- Quantified differences in adopted and unadopted implementation strategies across contexts. Identified distinct implementation priorities: capacity building in low resource settings versus system integration in high resource settings.

What is the implication, and what should change now?

- Implementation strategies should be tailored to local healthcare system maturity.
- Focus should be put on scaling basic mobile platforms while building workforce capacity in low resource settings.

faces distinct challenges across resource settings. Resource-rich countries primarily grapple with integration into existing healthcare systems and workflow adaptation, while resource-limited countries often confront more fundamental barriers in technological infrastructure and healthcare workforce capacity. Implementation research suggests high satisfaction and acceptability of mHealth interventions among stroke survivors (17,32), particularly regarding home-based therapy convenience (10). However, implementation gaps remain underexplored, notably pronounced in the identification of context-specific determinants and strategy adoption patterns making it difficult to develop targeted strategies that can effectively bridge the know-do gap in stroke prevention across settings (33-37).

Implementation science frameworks offer valuable theoretical guidance for analyzing these complex implementation dynamics. The CFIR (Consolidated Framework for Implementation Research) provides a theoretical foundation for analyzing determinants in implementation, particularly relevant for mHealth interventions where technological innovation intersects with varying healthcare system capacities. The ERIC (Expert Recommendations for Implementing Change) complements this by offering a taxonomy of evidence-based implementation strategies (38-41). While the updated version of CFIR [2022] (42,43) focuses on user feedback rather than theoretical advances, the initial version [2009] (38) better analyzes strategy-barrier alignment when paired with ERIC (39,41)—a critical but understudied aspect of mHealth implementation (44).

Despite growing evidence supporting mHealth interventions' effectiveness in stroke prevention, three key knowledge gaps persist. First, there lacks systematic understanding of implementation determinants in different resource settings. Second, the alignment between implementation strategies and contextual barriers remains poorly documented, particularly in comparing resource-rich versus resource-limited contexts. Third, evidence-based guidance for selecting and tailoring context-appropriate implementation strategies remains limited.

Objective

This study aims to address these gaps by: (I) identify implementation determinants across different income-specific contexts using CFIR; (II) evaluate strategy-barrier alignment through CFIR-ERIC mapping; and (III) propose context-specific recommendations for selecting and adapting implementation strategies. By systematically analyzing implementation patterns across resource settings, this study seeks to advance understanding of how to effectively translate mHealth interventions for stroke prevention into sustainable real-world practice. We present this article in accordance with the PRISMA-ScR reporting checklist (available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-25-20/rc) (45).

Methods

Study design and theoretical framework

Our theoretical approach integrated two complementary frameworks: CFIR provided a comprehensive lens for identifying implementation determinants, while ERIC taxonomy offered a structured approach for mapping implementation strategies. We selected the 2009 CFIR version for three methodological reasons: (I) it has been extensively validated in implementation research with over a decade of empirical application; (II) the CFIR-ERIC Barrier Buster Tool (v0.53)[1], which was essential for our strategy-barrier alignment analysis, was developed and validated specifically for the 2009 framework constructs; and (III) no comparable validated mapping tool currently exists for the 2022 CFIR version. While the 2022 update offers valuable user-centered refinements for digital health, it mainly refines definitions rather than structure. For systematically mapping barriers to strategies, the 2009 version with its validated CFIR-ERIC Barrier Buster Tool provided the most rigorous approach. This dual-framework approach enabled systematic examination of strategy-barrier alignment patterns across different resource settings.

Information sources and search strategy

Literature search was conducted in six databases: English databases included PubMed, Web of Science, the Cochrane Library, and Scopus; Chinese databases included CNKI (China National Knowledge Infrastructure) and Wanfangdata (WanFang Digital Database). The search was limited to articles published between 1 January 2013 and 31 December 2023 (search conducted on 5 January 2024). The search strategy combined four concept blocks using Medical

[1] Downloaded from https://cfirguide.org/choosing-strategies/.

Subject Headings (MeSH) terms and keywords: (I) stroke; (II) recurrence, recurrent or secondary prevention; (III) mHealth interventions; and (IV) implementation factors (determinants, barriers, facilitators, etc.). All retrieval processes were independently conducted by two reviewers (J.P. and H.T.), the final search results were exported to EndNote V.21 and duplicates were removed. Detailed search terms can be found in Appendix 1. Additional relevant studies were identified through manual searching of reference lists and citation tracking of included studies.

Eligibility criteria

Studies were eligible if they: (I) examined mHealth interventions for stroke prevention or management; (II) contained implementation descriptions; (III) were conducted in any resource setting as classified by Organization for Economic Co-operation and Development (OECD) criteria (46); and (IV) used any empirical study design [e.g., randomized controlled trials (RCTs), cohort studies, qualitative studies] or synthesized empirical evidence (e.g., meta-analyses). We excluded studies utilizing specialized medical devices (e.g., electromyographic biofeedback, physiological data acquisition systems, real-time visual feedback systems), robot-assisted interventions, or those involving participants with significant comorbidities (obstructive sleep apnea, cognitive impairment, severe psychiatric disorders, refractory epilepsy). Additionally, we excluded conference abstracts, letters, and studies conducted exclusively in acute care settings. Both English and Chinese language publications were considered.

Study selection and data extraction

The same pair of independent reviewers screened the titles/abstracts and full texts against eligibility criteria, with disagreements resolved through discussion or third-reviewer adjudication (Xiru Yu). A data charting form was jointly designed by the investigator team a priori to extract: study information (title, first author, year of publication, country/region, study design, etc.), mHealth intervention and control group details, CFIR-categorized implementation determinants (enablers or barriers) (38,43,47), quality assessment results.

CFIR-ERIC mapping

First, two reviewers independently coded implementation barriers according to CFIR constructs, reaching consensus through discussion. Second, implementation strategies were extracted using the ERIC taxonomy. Third, CFIR-categorized barriers were mapped to expert-recommended strategies using the CFIR-ERIC Barrier Buster Tool V0.53, identifying Level 1 strategies (endorsed by >50% experts) for each barrier (40). Finally, we summarized strategy-barrier alignment by calculating "matches per study" (reported Level 1 strategies in implementation) and "missing per study" (non-reported Level 1 strategies in implementation) rates, comparing patterns between low and high settings. Coding agreement analysis for CFIR coding was done (Appendix 2).

Quality assessment

We adapted the Standard Quality Assessment Criteria for Evaluating Primary Research Papers (48), rather than use implementation science specific quality criteria, as guide to provide an overview of the quality of studies with a validated 9-item checklist applicable across various research fields. Following previous implementation research approaches (49), we applied this assessment framework to both quantitative and qualitative studies (48,49) (Appendix 3). Each item was scored on a 3-point scale (0–2), with items marked "N/A" excluded from scoring. Final quality scores were calculated as the ratio of actual to possible points, categorizing studies as low (0–0.61), medium (0.67–0.79), or high quality (0.83–1.00). We note that while implementation science has specific reporting guidelines, such as Template for Intervention Description and Replication (TIDieR) and Standards for Reporting Implementation Studies (StaRI) Statement, which could provide additional insights into implementation quality, our quality assessment focused on evaluating the methodological rigor across different study designs. Two reviewers conducted assessments independently, resolving discrepancies through discussion or consultation with a third reviewer.

Data synthesis

We employed a convergent integrated approach to synthesize the quantitative and qualitative implementation evidence. Descriptive data from included studies were charted in Microsoft Excel 2019. Findings were organized according to: (I) study and intervention characteristics; (II) CFIR-categorized implementation determinants; (III) ERIC-classified implementation strategies; and (IV)

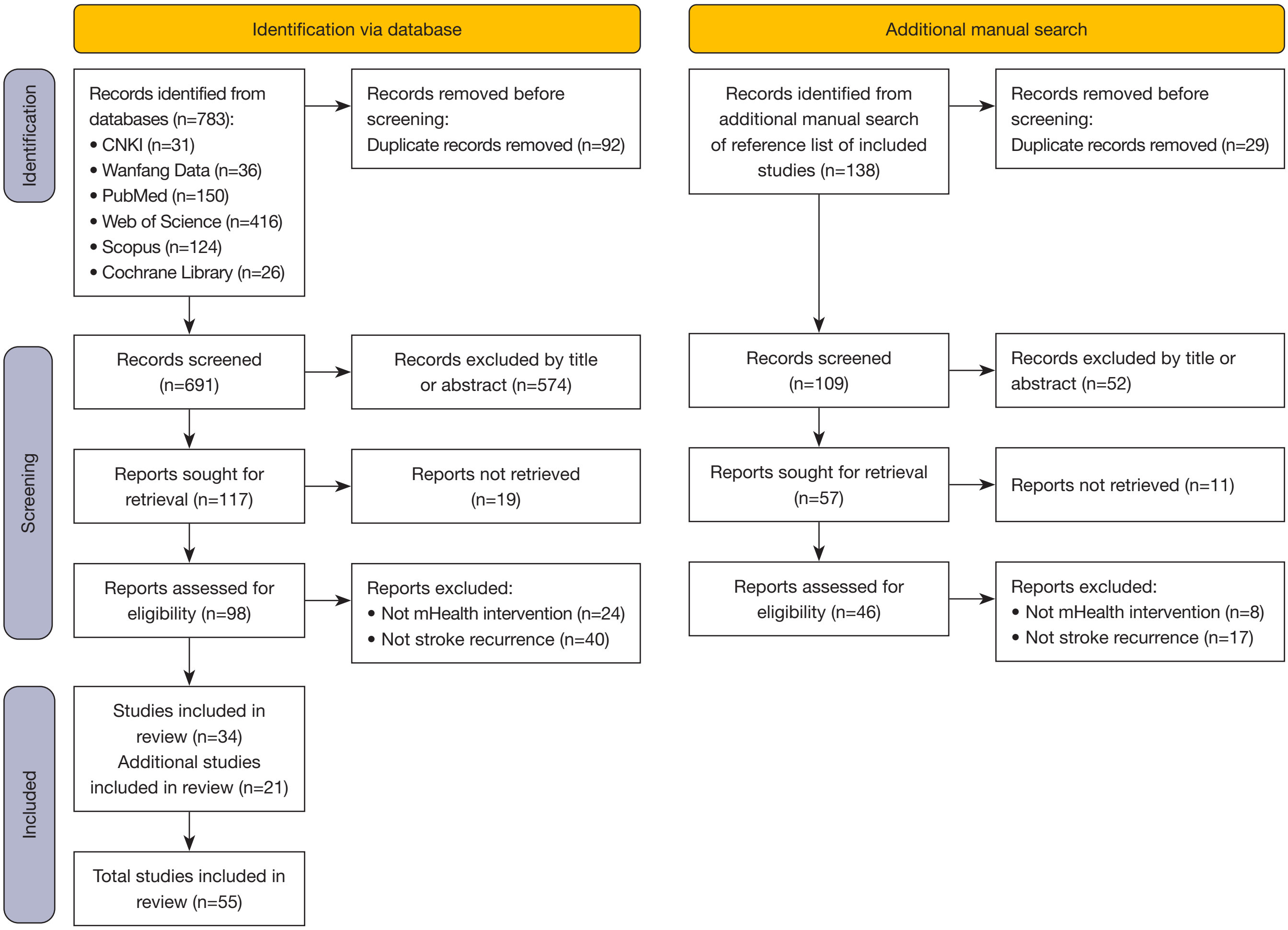

Figure 1 PRISMA flow diagram for included papers. PRISMA, Preferred reporting items for Systematic Review and Meta-Analyses.

strategy-barrier alignment patterns for resource-rich and resource-limited contexts. The frequency of CFIR constructs and ERIC strategies were summarized, while narrative synthesis explored patterns across resource settings. The synthesis emphasized actionable insights for selecting and adapting implementation strategies across contexts.

Statistical analysis

We conducted statistical analyses to examine differences in strategy alignment patterns between resource settings. First, we assessed data normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. For non-normally distributed data, we employed Mann-Whitney *U* tests with exact significance calculations. Additionally, given the small sample sizes in each group (n<30), we employed bootstrap methods to obtain robust estimates of means, standard deviations, and confidence intervals for strategy alignment patterns. Bias-corrected and accelerated (BCa) 95% confidence intervals (CIs) were calculated for mean differences between resource settings. Statistical significance was assessed using bootstrap-derived P values. All analyses were performed using SPSS version 26.0.

Results

Literature search and study selection

The initial search identified 783 articles, of which 92 were duplicates and 574 were removed based on titles and abstracts. Full-text screening was conducted on 117 studies, of which 19 could not obtain the full text, 24 did not meet our criteria for mHealth interventions, and 40 were not related to stroke recurrence. In the additional manual search, 138 articles were retrieved, including 29 duplicates, 52 excluded by title or abstract, 11 could not obtain the full text, 8 did not align with the definition of mHealth interventions, and 17 were unrelated to stroke recurrence. Ultimately, 55 articles were included (*Figure 1*).

Characteristics of included studies

Publication trends and study design

Among the included 55 studies spanning 2013–2023 (*Table 1*), 74.5% published since 2019, indicating growing research interest in this field. RCTs constituted the majority (49.1%) of study designs, followed by qualitative studies (11.8%), pilot studies (10.1%), and observational studies (10.1%). Forty-seven used quantitative research checklists, 5 qualitative, and 3 both. Quality assessment suggested high quality in 43.6% of studies, with 23.6% rated as low quality, reflecting varied methodological rigor across the literature. This distribution reflects an emphasis on generating high-quality evidence while maintaining methodological diversity.

Geographical distribution and implementation settings

Studies originated from diverse geographical locations, with China (45.5%) and the United States of America (USA) (16.9%) contributing the largest proportions. The distribution between low and high resource settings was nearly balanced, with 29 studies (52.7%) conducted in low resource settings, enabling meaningful cross-context comparisons. This geographical spread provides valuable insights into implementation variations across different healthcare systems and resource settings.

mHealth intervention characteristics

Technology platforms and features

The interventions utilized various technological platforms, including smartphone applications (APPs) (49.1%), instant messaging systems (IMS) (25.5%), web portals (14.5%), personal social media (14.5%), video-teleconferencing (5.5%), and work-oriented social media (3.6%). Many interventions integrated multiple platforms to enhance functionality and accessibility. These platforms were typically enhanced with features such as personalized lifestyle modification guidance, family engagement modules, real-time healthcare provider interactions, remote monitoring capabilities through Bluetooth devices, integrated condition-specific management tools, etc.

Implementation determinants analysis

CFIR framework application

CFIR constructs frequency suggested distinct patterns in implementation determinants across settings (*Table 2*). Of the included 55 studies, "Evidence strength & Quality" (mentioned in 32 studies), "Adaptability" (27 studies), and "Complexity" (24 studies) emerged as predominant concerns among Intervention Characteristics. In the Outer Setting, "Patient Needs & Resources" was most frequently mentioned (39 studies). The Inner Setting suggested "Implementation Climate" (24 studies) and "Available Resources" (22 studies) as key factors. For Individual Characteristics, "Knowledge & Beliefs about the Intervention" (6 studies) and "Self-efficacy" (5 studies) had relatively higher frequency. Within Process dimensions, "Executing" (10 studies) and "Reflecting & Evaluating" (9 studies) were commonly cited. Summary of findings on barriers and enablers using CFIR are elaborated in the Appendix 4. Full records of barriers identified are documented in table online: https://cdn.amegroups.cn/static/public/mhealth-25-20-1.xlsx.

Cross-context comparison

Comparison of included studies (n=52, excluding meta-analyses due to their inability to be geographically categorized for resource setting classification) across CFIR dimensions suggested distinct patterns between resource-rich (n=23) and resource-limited contexts (n=29). Within Intervention Characteristics, both frequently reported "Evidence Strength & Quality" (16/29 *vs.* 13/23), "Adaptability" (16/29 *vs.* 9/23), and "Complexity" (16/29 *vs.* 8/23), while differences emerged in "Relative Advantage" (9/29 *vs.* 4/23) and "Design Quality & Packaging" (2/29 *vs.* 9/23). In the Outer Setting, "Patient Needs & Resources" showed consistently high frequency (20/29 *vs.* 16/23). The Inner Setting suggested similar emphasis on "Implementation Climate" (13/29 *vs.* 10/23) and "Available Resources" (11/29 *vs.* 10/23), but differences in "Access to knowledge & information" (11/29 *vs.* 5/23) and "Networks & Communications" (4/29 *vs.* 0/23). For Individual Characteristics, "Self-efficacy" received universal attention (3/29 *vs.* 2/23), yet differentiated in "Knowledge & Beliefs about the Intervention" (5/29 *vs.* 10/23). In the Process dimension, "Executing" were prioritized comparably between settings (6/29 *vs.* 4/23), while diverging on

Table 1 Characteristics of studies included in the analysis (n=55)

No.	Author, year	Country	Resource setting†	Study type	No. of participants	mHealth intervention	Quality rating
1	Denham *et al.* (50), 2018	Australia	High	Pilot	19	Web portals: prevent 2nd stroke	0.83 (high)
2	Cadilhac *et al.* (51), 2020	Australia	High	Pilot	29+25	IMS and smartphone APP: iVERVE system	0.83 (high)
3	Clancy *et al.* (52), 2022	Australia	High	Cross-sectional	333+21	Web portals: prevent 2nd stroke	0.94 (high)
4	Kamoen *et al.* (53), 2020	Belgium	High	Pilot	133	Web portals and APP: beroertecoach.be	0.89 (high)
5	Sakakibara *et al.* (54), 2017	Canada	High	Observational	N/A	IMS (telephone-based)	0.78 (medium)
6	Lin *et al.* (55), 2014	China	Low	RCT	12+12	APP: SHEMA	0.67 (medium)
7	Kang *et al.* (56), 2019	China	Low	RCT	38+38	APP (video-guided)	0.83 (high)
8	Gong *et al.* (57), 2019	China	Low	Observational	N/A	Not specified	0.67 (medium)
9	Wu *et al.* (58), 2019	China	Low	RCT	N/A	APP and IMS: SINEMA	0.86 (high)
10	Chung *et al.* (59), 2020	China	Low	RCT	29+27	APP (video-guided)	0.78 (medium)
11	Wang *et al.* (60), 2020	China	Low	RCT	97+98	APP: BHHM-led mHealth follow-up, Bluetooth devices	0.83 (high)
12	Yan *et al.* (25), 2021	China	Low	RCT	615+611	APP and IMS: SINEMA	0.89 (high)
13	Zhang *et al.* (61), 2020	China	Low	Cohort	157+101	Personal social media: WeChat	0.78 (medium)
14	Lv *et al.* (62), 2021	China	N/A	Systematic review and meta-analysis	1,583	Not specified	0.83 (high)
15	Li *et al.* (63), 2023	China	Low	Cohort	123+65	APP: BAMA doctor (Philips)	0.78 (medium)
16	Hu *et al.* (64), 2023	China	Low	Qualitative	15	Not specified	1.00 (high)
17	Liao *et al.* (65), 2013	China‡	Low	RCT	110+130	Not specified	0.39 (low)
18	Dong *et al.* (66), 2019	China‡	Low	RCT	99+99	Personal social media: WeChat	0.61 (low)
19	Liu *et al.* (67), 2020	China‡	Low	RCT	100+100	Personal social media: WeChat	0.61 (low)
20	Pan *et al.* (68), 2021	China‡	Low	Qualitative	N/A	Not specified	0.39 (low)
21	Yang *et al.* (69), 2022	China‡	Low	RCT	38+39	Work-oriented social media: DingTalk	0.83 (high)
22	Liu *et al.* (70), 2021	China‡	Low	RCT	50+50	APP: Jiangkangdongguan	0.61 (low)
23	Hu *et al.* (71), 2022	China‡	Low	RCT	60+60	Personal social media: WeChat	0.55 (low)
24	Li *et al.* (72), 2022	China‡	Low	RCT	40+40	Not specified	0.61 (low)
25	Xu *et al.* (73), 2022	China‡	Low	RCT	50+50	Personal social media: WeChat	0.39 (low)

Table 1 *(continued)*

Table 1 *(continued)*

No.	Author, year	Country	Resource setting†	Study type	No. of participants	mHealth intervention	Quality rating
26	Ye *et al.* (74), 2022	China‡	Low	RCT	30+30	Personal social media: WeChat	0.50 (low)
27	Lin *et al.* (75), 2023	China‡	Low	RCT	60+60	Personal social media: WeChat	0.67 (medium)
28	Qiu *et al.* (76), 2023	China‡	Low	RCT	38+38	APP: Golden Medal Nurse	0.72 (medium)
29	Wang *et al.* (77), 2023	China‡	Low	RCT	40+40	Work-oriented social media: DingTalk	0.67 (medium)
30	Yan *et al.* (78), 2023	China‡	Low	RCT	50+50	Personal social media: WeChat	0.61 (low)
31	Sarfo *et al.* (26), 2019	Ghana	Low	RCT	30+30	IMS, Bluetooth devices	0.78 (medium)
32	Pandian *et al.* (79), 2023	India	Low	RCT	2,150+2,148	IMS and web portals	1.00 (high)
33	Patel *et al.* (80), 2019	Indonesia	Low	Quasi-experimental	2,429+2,632	Web portals and APP: SMARThealth	0.83 (high)
34	Kariasa *et al.* (81), 2022	Indonesia	Low	Observational	22+22	APP: SenDiKa	0.83 (high)
35	Choi *et al.* (82), 2016	Korea	High	RCT	12+12	APP: MoU-Rehab	0.83 (high)
36	Spassova *et al.* (83), 2016	Luxembourg	High	RCT	46+48	IMS: CAPSYS	0.83 (high)
37	Puijk-Hekman *et al.* (84), 2017	Netherlands	High	Observational	N/A	Web portals: Vascular View	0.75 (medium)
38	Ranta *et al.* (85), 2014	New Zealand	High	Cohort	266	EDS tool	0.89 (high)
39	Ortiz-Fernández *et al.* (86), 2019	Spain	High	Pilot	N/A	APP and wearables: STARR	0.75 (medium)
40	Owolabi *et al.* (87), 2019	Sub-Saharan Africa§	Low	RCT	200+200	IMS	0.78 (medium)
41	Patomella *et al.* (88), 2021	Sweden	High	Quasi-experimental	6	APP: Make My Day	0.72 (medium)
42	Paul *et al.* (89), 2016	UK	High	RCT	15+8	APP: STARFISH	0.83 (high)
43	D'Anna *et al.* (90), 2021	UK	High	Observational	180+136	IMS	0.67 (medium)
44	Heron *et al.* (91), 2021	UK	High	Observational	N/A	APP: Brain-Fit app	0.83 (high)
45	O'Connor *et al.* (92), 2021	UK	N/A	Systematic Review and Meta-Analysis	N/A	APP (with behavior change techniques)	0.75 (medium)
46	Chumbler *et al.* (93), 2015	USA	High	RCT	23+20	Video-teleconferencing	0.78 (medium)
47	Jenkins *et al.* (94), 2016	USA	High	Qualitative	60	APP, Bluetooth devices	0.83 (high)

Table 1 *(continued)*

Table 1 *(continued)*

No.	Author, year	Country	Resource setting†	Study type	No. of participants	mHealth intervention	Quality rating
48	van den Berg *et al.* (95), 2016	USA	High	RCT	31+32	APP (loaded with customized, standardized exercises)	0.83 (high)
49	Jhaveri *et al.* (96), 2017	USA	High	Pilot	N/A	APP and IMS (for videoconferencing) on an iPad	0.94 (high)
50	Ramirez *et al.* (97), 2017	USA	High	Qualitative	19	APP on an Android tablet	0.83 (high)
51	Schwamm *et al.* (98), 2019	USA	High	Qualitative	N/A	APP, IMS, Web portals	0.32 (low)
52	Vilme *et al.* (99), 2019	USA	High	Qualitative	N/A	Video-teleconferencing, IMS, Web portals	0.56 (low)
53	Anderson *et al.* (100), 2022	USA	High	Pilot	193	Video-teleconferencing	0.78 (medium)
54	Verma *et al.* (101), 2022	USA	High	Qualitative	N/A	APP, IMS	0.67 (medium)
55	Wang *et al.* (102), 2023	USA	N/A	Systematic Review and Meta-Analysis	799	IMS and APP: not specified	0.89 (high)

†, exclusively focus on examining the implementation settings of mHealth within non-reviews (n=51). Classification based on OECD Country Classification 2022 (Source: http://www.oecd.org/trade/topics/export-credits/arrangement-and-sector-understandings/financing-terms-and-conditions/), the downloaded file was uploaded as an additional file. ‡, Chinese literature. §, Sub-Saharan Africa is classified as a low-resource setting due to its overall healthcare infrastructure limitations and significant public health challenges. APP, applications; BHHM, Behavioral and Health Habits Model; EDS, Electronic Decision Support; IMS, instant messaging systems; mHealth, mobile health; N/A, not applicable; SHEMA, stroke health-education mobile.

"Reflecting & Evaluating" (1/29 *vs.* 6/23).

Strategy-barrier alignment

Implementation strategy recommendations

Identified CFIR implementation determinants and the expert-endorsed ERIC strategies mapped for 55 included studies were organized in table online: https://cdn.amegroups.cn/static/public/mhealth-25-20-1.xlsx. *Table 3* illustrates the most frequently recommended ERIC strategies among Level 1 strategies, assessment-focused approaches were predominantly endorsed, with "Assess for readiness and identify barriers and facilitators" recommended in 94.5% of studies. Leadership engagement strategies were also prioritized, as evidenced by "Identify and prepare champions" being recommended in 92.7% of studies. Knowledge-sharing and stakeholder engagement strategies followed closely, with both "Capture and share local knowledge" and "Involve patients/consumers and family members" endorsed in 87.3% of studies. Consensus-building and educational strategies also featured prominently, with "Conduct educational meetings", "Conduct local consensus discussions", and "Identify early adopters" each recommended in 85.5% of studies. Additional frequently recommended strategies included "Creating a learning collaborative" and "Tailoring strategies" (83.6% each), followed by "Promoting adaptability" and "Conducting local needs assessment" (81.8% each). Strategies also focused on iterative improvement and stakeholder feedback, such as "Conduct cyclical small tests of change" and "Obtain patient/family feedback", were recommended in 78.2% of studies.

For Level 2 strategies, "Develop academic partnerships" emerged as the most frequently recommended approach (60.0%), followed by "Intervene with patients/consumers to enhance uptake & adherence" (50.9%). Knowledge transfer strategies, including "Shadow other experts" and "Work with educational institutions", were each recommended in 47.1%

Table 2 CFIR constructs frequency

CFIR construct	All included studies (empirical studies and meta-analyses, n=55)	Empirical studies (n=52)	
		Low resource settings (n=29)	High resource settings (n=23)
Intervention source	0	0	0
Evidence strength & quality	32†	16†	13†
Relative advantage	14†	9†	4
Adaptability	27†	16†	9†
Trialability	2	1	1
Complexity	24†	16†	8†
Design quality & packaging	13†	2	9†
Cost	17†	8†	9†
Patient needs & resources	39†	20†	16†
Cosmopolitanism	1	1	0
Peer pressure	0	0	0
External policy & incentives	6	4	2
Structural characteristics	2	1	1
Networks & communications	5	4	0
Culture	5	4	1
Implementation climate	24†	13†	10†
Tension for change	1	1	0
Compatibility	2	1	1
Relative priority	0	0	0
Organizational incentives & rewards	0	0	0
Goals and feedback	1	1	0
Learning climate	0	0	0
Readiness for implementation	5	3	12†
Leadership engagement	4	4	0
Available resources	22†	11†	10†
Access to knowledge & information	17†	11†	5
Knowledge & beliefs about the Intervention	6	5	10†
Self-efficacy	5	3	2
Individual stage of change	1	0	1
Individual Identification with organization	0	0	0
Planning	4	1	3
Opinion leaders	1	1	0
Formally appointed internal implementation leaders	0	0	0
Champions	0	0	0
External change agents	0	0	0
Key stakeholders	3	2	1
Patients/customers	8	3	4
Executing	10	6†	4
Reflecting & evaluating	9	1	6

†, CFIR construct with top 10 frequencies. CFIR, Consolidated Framework for Implementation Research.

Table 3 Most frequently recommended ERIC strategies for identified CFIR barriers (top 20)

Strategy level	ERIC strategy	Frequency	Proportion (%)
Level 1	Assess for readiness and identify barriers and facilitators	52	94.5
	Identify and prepare champions	51	92.7
	Capture and share local knowledge	48	87.3
	Involve patients/consumers and family members	48	87.3
	Conduct educational meetings	47	85.5
	Conduct local consensus discussions	47	85.5
	Identify early adopters	47	85.5
	Create a learning collaborative	46	83.6
	Tailor strategies	46	83.6
	Promote adaptability	45	81.8
	Conduct local needs assessment	45	81.8
	Conduct cyclical small tests of change	43	78.2
	Obtain and use patients/consumers and family feedback	43	78.2
	Facilitation	42	76.4
	Inform local opinion leaders	41	74.5
	Conduct educational outreach visits	41	74.5
	Develop educational materials	40	72.7
	Use advisory boards and workgroups	40	72.7
	Alter incentive/allowance structures	39	70.9
	Build a coalition	39	70.9
Level 2	Develop academic partnerships	33	60.0
	Intervene with patients/consumers to enhance uptake & adherence	28	50.9
	Shadow other experts	27	49.1
	Work with educational institutions	26	47.3
	Facilitate relay of clinical data to providers	25	45.5
	Audit and provide feedback	25	45.5
	Alter patient/consumer fees	25	45.5
	Involve executive boards	25	45.5
	Develop and organize quality monitoring systems	24	43.6
	Use train the trainer strategies	24	43.6
	Use other payment schemes	24	43.6
	Use data experts	23	41.8
	Increase demand	22	40.0
	Develop resource sharing agreements	21	38.2
	Mandate change	21	38.2
	Place innovation on fee for service lists/formularies	21	38.2
	Fund and contract for clinical innovation	20	36.4
	Make billing easier	20	36.4
	Provide clinical supervision	19	34.5
	Use an implementation adviser	19	34.5

CFIR, Consolidated Framework for Implementation Research; ERIC, Expert Recommendations for Implementing Change.

of studies. Clinical data management and quality assurance strategies, such as “Facilitate relay of clinical data to providers” and “Audit and provide feedback”, were endorsed in 45.5% of studies. Financial considerations were addressed through strategies like “Alter patient/consumer fees” (49.1%) and “Use other payment schemes” (41.8%). Organizational support mechanisms, including “Involve executive boards” (47.3%) and “Develop and organize quality monitoring systems” (38.2%), were also prominently featured.

Strategy alignment patterns

When comparing CFIR-ERIC tool-recommended Level 1 strategies with reported implementation approaches, we observed variations in strategy adoption across settings (*Table 4*). Studies conducted in low resource settings (n=29) demonstrated a higher average number of strategies matches with Level 1 strategies (9.40±4.31 matches per study) compared to those conducted in high resource settings (n=23, 7.16±2.44 matches per study). However, studies conducted in low resource settings also showed more gaps between the recommended strategies and the reported strategies (9.53±5.49 versus 8.00±4.63 per study), suggesting distinct patterns in strategy selection and implementation approaches across resource settings.

Table 4 Implementation strategy alignment with CFIR-ERIC Level 1 recommendations

No.	Year	Resource setting	First author	Strategy alignment (implemented strategies *vs.* Level 1 strategies)	
				Matches (n)	Missing (n)
1	2013	Low	Liao CL	6	10
2	2014	Low	Lin KH	4	19
3	2014	High	Ranta A	4	6
4	2015	High	Chumbler NR	2	2
5	2016	High	Berg M. van den	10	20
6	2016	High	Choi YH	8	17
7	2016	High	Jenkins C	7	6
8	2016	High	Paul L	8	20
9	2016	High	Spassova L	9	7
10	2017	High	Jhaveri MM	9	8
11	2017	High	Puijk-Hekman S	7	4
12	2017	High	Ramirez M	8	7
13	2017	High	Sakakibara BM	8	7
14	2018	High	Denham AMJ	8	7
15	2019	Low	Dong JP	15	2
16	2019	Low	Gong E	11	9
17	2019	Low	Kang YN	1	0
18	2019	High	Ortiz-Fernández L	8	8
19	2019	Low	Owolabi MO	7	21
20	2019	Low	Patel A	8	9
21	2019	Low	Sarfo FS	7	7
22	2019	High	Schwamm LH	7	12

Table 4 *(continued)*

Table 4 (continued)

No.	Year	Resource setting	First author	Strategy alignment (implemented strategies *vs.* Level 1 strategies)	
				Matches (n)	Missing (n)
23	2019	High	Vilme H	7	12
24	2019	Low	Wu N	8	9
25	2020	High	Cadilhac DA	7	7
26	2020	Low	Chung BPH	7	7
27	2020	High	Kamoen O	6	8
28	2020	Low	Liu ZZ	10	16
29	2020	Low	Wang S	8	7
30	2020	Low	Yan LL	7	8
31	2020	Low	Zhang Y	7	7
32	2021	High	D'Anna L	4	6
33	2021	High	Heron N	12	9
34	2021	Low	Liu Q	20	1
35	2021	N/A	Lv M	5	16
36	2021	N/A	O'Connor SR	7	28
37	2021	Low	Pan F	4	9
38	2021	High	Patomella AH	9	9
39	2021	Low	Yang YP	19	3
40	2022	High	Anderson JA	5	5
41	2022	High	Clancy B	4	6
42	2022	Low	Hu LL	14	9
43	2022	Low	Kariasa IM	7	9
44	2022	Low	Li YF	13	9
45	2022	High	Verma A	12	8
46	2022	Low	Xu W	13	13
47	2022	Low	Ye QM	12	1
48	2023	Low	Hu Y	9	9
49	2023	Low	Li DM	6	5
50	2023	Low	Lin XX	14	15
51	2023	Low	Pandian JD	7	7
52	2023	Low	Qiu M	12	17
53	2023	Low	Wang HF	11	18
54	2023	N/A	Wang SCY	3	12
55	2023	Low	Yan WB	10	14

CFIR, Consolidated Framework for Implementation Research; ERIC, Expert Recommendations for Implementing Change.

To evaluate the statistical significance of these differences, we followed a systematic analytical approach (*Tables 5,6*). Normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) indicated non-normal distributions ($P<0.05$), leading us to employ Mann-Whitney U tests with exact significance. For matches per study, the test revealed a marginally significant difference (U=243.0, exact two-tailed P=0.09, exact one-tailed P=0.047). Bootstrap analyses (5,000 samples) provided robust confirmation and precise estimates of the effect size: the mean difference was 2.20 (BCa 95% CI: 0.36–4.12), with a bootstrap-derived P value of 0.03, indicating low-resource settings implemented on average 2.2 more recommended strategies per study. For missing strategies, the mean difference of 0.57 (BCa 95% CI: −2.29 to 3.38) suggested no meaningful difference between settings. Complete statistical outputs are provided in Appendix 5.

Table 5 Statistical comparison of strategy-barrier alignment between low and high resource settings

Test statistic	Matches	Missing
Mann-Whitney $U^{\dagger}$	243.000	282.000
Wilcoxon W	519.000	558.000
Z	−1.684	−0.956
Asymp. Sig. (2-tailed)	0.092	0.339
Exact Sig. (2-tailed)	0.093	0.344
Exact Sig. (1-tailed)	0.047	0.172
Point probability	0.001	0.002
Monte Carlo Sig. (2-tailed)‡		
Sig.	0.096	0.339
99% confidence interval		
Lower bound	0.089	0.327
Upper bound	0.104	0.351
Monte Carlo Sig. (1-tailed)‡		
Sig.	0.047	0.168
99% confidence interval		
Lower bound	0.042	0.158
Upper bound	0.053	0.178

†, grouping variable: resource setting (high/low); ‡, based on 10,000 sampled tables with starting seed 1314643744. Sig., significance.

Sensitivity analysis: quality-weighted strategy alignment

The quality-weighted analysis assigned greater weight to higher-quality studies while retaining all data. For matches per study, the difference between low-resource (weighted mean =9.32, 95% CI: 8.75–9.91) and high-resource settings (weighted mean =7.31, 95% CI: 6.95–7.66) remained statistically significant (weighted mean difference =2.01, 95% CI: 1.35–2.69, $P<0.001$). For missing strategies, no significant difference was found between low-resource settings (mean: 9.21, 95% CI: 8.51–9.89) and high-resource settings (mean: 8.59, 95% CI: 7.96–9.25), consistent with our primary analysis. Refer to Appendix 5 for details.

Discussion

Key findings

This study suggested three core findings about mHealth implementation for stroke recurrence prevention: (I) implementation determinants between low and high resource settings; (II) differential strategy-barrier alignment patterns between resource-rich and resource-limited contexts; and (III) varying context-specific implementation priorities across settings.

First, distinctive implementation patterns were uncovered between low and high resource settings across multiple CFIR domains. While resource-limited contexts emphasized demonstrating relative advantage, ensuring access to knowledge and information access, and forging networks, resource-rich contexts focused more on intervention

Table 6 Bootstrap analysis of strategy-barrier alignment differences between resource settings

Outcome	Low-resource settings (n=29)	High-resource settings (n=23)	Mean difference†	P value
Matches per study	9.55 (4.31)	7.35 (2.44)	2.20	0.03
Missing per study	9.31 (5.49)	8.74 (4.63)	0.57	–

Data are presented as mean (standard deviation). †, mean difference calculated as low-resource minus high-resource settings; 95% CI represents BCa bootstrap CI based on 5,000 samples. Standard deviation area also provided. BCa, bias-corrected and accelerated; CI, confidence interval.

refinement through design quality and systematic evaluation.

Second, examination of ERIC strategy recommendations suggested consistent patterns across implementation settings. Assessment-focused approaches were predominantly endorsed, followed by leadership engagement through shaping champions. Knowledge-sharing and stakeholder engagement strategies were also considered, suggesting broad expert consensus on fundamental implementation strategies regardless of resource setting.

Third, examination of strategy-barrier alignment studies revealed complex patterns between settings through multiple statistical approaches. While Mann-Whitney *U* tests showed marginally significant differences in strategy adoption (exact P=0.09, one-tailed P=0.047), bootstrap analyses provided more robust evidence of significant differences (mean difference =2.20, bootstrap BCa 95% CI: 0.36–4.12, P=0.03). This convergent evidence indicates that studies in low-resource settings implemented on average 2.2 more recommended strategies per study. Conversely, gaps between recommended and reported strategies showed no significant differences across both analytical approaches (Mann-Whitney *U* P=0.34; bootstrap BCa 95% CI: −2.29 to 3.38), suggesting that implementation challenges persist regardless of resource availability. Importantly, these patterns remained robust in sensitivity analyses that accounted for study quality.

Strengths and limitations

This study advances implementation science in three aspects. First, by systematically mapping implementation determinants through CFIR and connecting them to recommended strategies via ERIC taxonomy, we provide insights into both the distribution of specific barriers and their corresponding evidence-based solutions across settings, moving beyond simple barrier identification to actionable implementation guidance. Second, incorporating bilingual literatures enhances the findings' representatives to some degree, especially in understanding implementation dynamics in emerging economies. Third, strategy-barrier alignment patterns offer practical guidance for choosing and tuning implementation approaches considering local conditions, enabling policymakers and program implementers to prioritize context-appropriate strategies that address the most pressing barriers in their specific resource environment. Fourth, our multi-faceted statistical approach strengthens the validity of our findings. By employing both non-parametric tests appropriate for non-normal distributions and bootstrap methods for robust estimation, we provide convergent evidence for our key findings.

Several limitations warrant consideration. First, sparse implementation details in primary studies and language constraints reflect broader gaps between knowledge translation and implementation research, where fragmented evidence ecosystems delay real-world impact (103,104). Second, our strategy-barrier alignment analysis relied exclusively on the information reported by authors, so we cannot determine whether observed gaps reflect actual implementation deficits or underreporting. Third, while our use of the 2009 CFIR version enabled validated strategy-barrier mapping, it may not fully capture user-centered dynamics particularly relevant to mHealth. The 2022 update's refinements could offer additional insights into mHealth adoption patterns. Fourth, our review lacks longitudinal data and causal mechanism analyses necessary to establish long-term effectiveness of identified strategies. Finally, our search cutoff of December 2023 may not capture recent advances in mHealth implementation, particularly given the rapid evolution of digital health technologies accelerated by the coronavirus disease 2019 (COVID-19) pandemic. This temporal limitation means emerging post-pandemic implementation strategies may not be reflected in our findings, highlighting the need for regular systematic updates in this rapidly evolving field.

Comparison with similar research

Our findings resonate with literatures emphasizing the need for embedded approaches in mHealth implementation (103,104), where policymakers, technologists, and end-users collaboratively design interventions to address localized barriers, such as family dynamics paradoxically reducing mHealth willingness when communication is strong (64,105).

Current preventive strategies for stroke recurrence have gained critical priority in public health agendas, driven by the escalating global burden of stroke and its recurrent events (29). While existing literature positions mHealth as a cost-effective (106) and accessible (1) solution under resource constraints, our findings extend this understanding by summarizing the distinct patterns of implementation determinants and strategy adoption that emerge in different resource contexts, thereby providing a more nuanced framework for context-specific implementation planning.

Explanations of findings

The observed patterns in implementation determinants and strategy adoption may be explained by several factors. The divergent focus between low and high resource settings reflects their different stages of implementation maturity and resource availability. Low resource settings' emphasis on demonstrating intervention effectiveness and building fundamental capacity aligns with their need to establish basic implementation infrastructure, consistent with findings by Asige *et al.* who emphasized that rigorous effectiveness evaluation in real-world situations is a prerequisite before scaling up complex interventions in resource-constrained settings (107). High resource settings' focus on intervention refinement and systematic evaluation reflects their more developed healthcare systems and existing digital infrastructure, as demonstrated by Ross *et al.*, who found that implementation in high-income countries often centers on interoperability with existing systems rather than fundamental capacity building (108). This also aligns with Greenhalgh *et al.*'s work showing how technology adoption in mature healthcare systems frequently emphasizes optimization over initial functionality (109).

The convergent statistical evidence for higher strategy adoption in resource-limited contexts warrants careful interpretation. The marginally significant Mann-Whitney *U* test (P=0.09) gained stronger support through bootstrap analysis (P=0.03). This pattern indicates that countries with limited resources may indeed be more motivated to adopt evidence-based strategies, a phenomenon documented by Iwelunmor *et al.* in their systematic review of implementation science in regions with restricted resources (110). The consistency between our primary and sensitivity analyses further strengthens this interpretation, as the quality-weighted analysis yielded similar effect sizes (2.01 *vs.* 2.20 strategies), indicating that higher-quality studies support this pattern. Meanwhile, the non-significant differences in implementation gaps across all analytical approaches (P=0.34 in primary analysis, P=0.22 in sensitivity analysis) suggest that structural barriers to comprehensive implementation transcend resource availability, aligning with Moucheraud *et al.*, who found that limited-resource settings often prioritize a subset of recommended strategies based on feasibility rather than attempting comprehensive implementation (111). The pattern also highlights the need for context-sensitive approach tailoring and implementation planning that considers both local implementation capacity and resource constraints, supporting Aarons *et al.*'s framework for adapting evidence-based practices across different service settings (112) and Shelton *et al.*'s findings on the importance of contextual fit in implementation success (113).

Implications and actions needed

Research implications

Future research should examine optimal strategy combinations and evaluate implementation effectiveness across different resource settings, with special focus on longitudinal, mixed-methods designs to disentangle causal mechanisms. Expanding multilingual evidence synthesis may also help understand implementation dynamics more comprehensively across diverse contexts. Building on our CFIR-ERIC mapping findings, future studies may further develop and validate context-specific implementation toolkits that provide actionable guidance for specific resource environments.

Practice implications

For practice, our findings suggest that implementation strategies should be tailored to local healthcare system maturity. Resource-limited countries tend to focus on scaling basic mobile platforms while building workforce capacity, whereas resource-rich countries typically prioritize integration with existing digital infrastructure. Future implementation efforts may benefit from considering these contextual patterns, though more research is needed to establish whether these approaches lead to optimal outcomes in their respective settings. Implementers in resource-limited settings might particularly benefit from focusing on the commonly underutilized but expert-recommended strategies identified in this study.

Policy implications

Policymakers should consider differential approaches to supporting mHealth implementation based on healthcare system context. In resource-limited settings, policies that support basic technological infrastructure development and healthcare workforce capacity building may create fertile ground for mHealth adoption. Conversely, in resource-rich settings, policies that facilitate interoperability standards and integration with existing health information systems may better address identified implementation barriers. Cross-cutting policy considerations include developing context-sensitive funding mechanisms that account for the different implementation priorities highlighted in this study and other researches.

Conclusions

This study reveals key disparities in mHealth implementation for stroke prevention between low- and high-resource settings. Low resource contexts prioritize foundational capacity (demonstrating intervention effectiveness, knowledge access), while high resource settings focus on refining interventions (design quality, evaluation). Our statistical analyses confirm that low resource settings demonstrate significantly higher adoption of expert-recommended strategies, yet face comparable implementation gaps, revealing a paradox between implementation ambition and realization. CFIR-ERIC mapping identifies universal adoption of assessment-focused and stakeholder engagement strategies, yet low resource settings exhibit higher strategy adoption alongside persistent gaps, potentially reflecting ambitious implementation efforts constrained by realistic limitations. These findings provide a structured framework for context-aware implementation, informing resource-sensitive strategies. Future research should explore causal mechanisms of strategy effectiveness and longitudinal impacts across diverse systems, particularly to understand why greater strategy adoption in resource-limited settings does not translate into fewer implementation gaps. To bridge know-do gaps, policymakers should develop tailored approaches that acknowledge these contextual differences, thereby enhancing the translation of effective mHealth interventions into sustainable real-world practice in secondary prevention of stroke globally.

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Footnote

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