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Mobile Application Intervention Effectiveness in Improving Hypertensive Patients Medication Adherence: A Systematic Review

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Abstract

Introduction: Hypertension and its complications are massive global health issues. Major limitations in hypertensive patients' treatment include suboptimal blood pressure control and nonadherence to medication. The popularity of telemedicine has risen in recent years. Mobile phone applications intervention in particular, provides features including medication-taking, refilling reminders, and biometric results tracker resulting in better health outcomes and improved medication adherence. This review aims to assess the effectiveness of mobile application in improving adherence in hypertensive patients. **Methods:** PubMed, Scopus, and Cochrane Library were searched with filters applied for studies published between 2013 and 2023 and content published in English with the keywords; telemedicine, mobile apps, medication adherence, and hypertension. These keywords were joined using Boolean operators for an effective search. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis Statement was followed for this systematic review. The Mixed Method Appraisal Tool was used to assess the quality of the included studies. The data was extracted by the authors and validated by another for accuracy and completeness. **Results:** Twelve studies ranging from moderate to high quality were included in this review. A total of 10 studies showed a statistically significant improvement ($p < 0.001$) in medication adherence with mobile apps intervention. The combined apps features from the mobile apps empower patients to be more adherent, involved and informed about their treatment progress. **Conclusion:** Hypertensive patients' medication adherence improved with mobile apps intervention. However, the heterogeneity of adherence measurement methods and apps functionality in the included studies calls for further studies to determine the effectiveness of specific mobile apps feature as well as the standardisation of the adherence measurement method used.

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Introduction

Hypertension, also known as high blood pressure (BP), and its related complications stand as prominent contributors to both morbidity and mortality. (Mills et al., 2017). Among the major problems in managing hypertensive patients include suboptimal blood pressure control and poor treatment adherence. Despite the availability and access to effective and safe medication, at least half of hypertensive patients fail to achieve their target blood pressure goals (Michalakeas et al., 2020).

Telemedicine is a form of supplement effort to achieve health objectives using wireless technologies such as mobile phones (Beleigoli et al., 2019). Given lower costs and greater patient engagement, telemedicine interventions such as mobile phone applications and wireless devices have been introduced for chronic disease management, including hypertension. (Morrissey et al., 2018). As effective management of hypertension is crucial for preventing cardiovascular disease, all possible tools should be used to help achieve target blood pressure levels, both for individuals and the population as a whole. This includes leveraging mobile phones, smartphones, and their various applications as approximately 85% of the world's population has mobile phone coverage (Cowie et al., 2016).

To address nonadherence, a few of the mobile applications' functions include medication-taking reminder, refilling reminders and biometric results trackers (Kumar et al., 2015). Recent studies regarding mobile applications intervention in managing hypertension and medication adherence improvement were found to have positive impacts (Ma et al., 2019). However, outcomes are inconsistent, with some studies showing no significant impact on blood pressure control despite better adherence (Moore, Neher et al. 2011, Rupert and Mounsey 2022). Factors influencing effectiveness include patient motivation, ease of use, and health literacy. These apps are particularly relevant for hypertension management due to the chronic nature of the condition, the need for remote monitoring, and the ability to provide personalized care plans.

Despite these advancements, there is a lack of systematic review evaluating the effectiveness of mobile applications intervention and the adherence measurement methods used. This paper aims to bridge the gaps in the existing literature, highlighting the potential of mobile apps in managing hypertension and improving patient outcomes.

Methodology

The Preferred Reporting Items for Systematic Reviews and Meta Analyses Protocols (PRISMA-P) was followed for this systematic review.

Eligibility criteria

Study Design: Both randomised and non-randomised control trial studies related to mobile applications intervention impact on the medication adherence in hypertensive patients were included in this paper.

Inclusion and exclusion criteria

The research focused on articles reporting studies about hypertensive patients of above 18 years and older, with mobile application intervention for medication adherence. Only full-text studies in English from 2013 to 2023 are included, excluding other types of telemedicine interventions.

Information Sources

The principal source of literature is from electronic bibliographic databases using a comprehensive search strategy via PubMed, Scopus, and Cochrane Library.

Search Strategy

The search strategy is developed to target three key domains: Medication Adherence, Hypertension, and Telemedicine. To ensure the search strategy used is effective, these three domains were joined together using the Boolean operator "AND" while the groups of keywords were joined with the Boolean operator "OR". The group of keywords for the domains are, (1) Medication Adherence; "Patient Compliance", "Drug Adherence", "Drug

Compliance", "Medication Noncompliance", "Medication Nonadherence", "Medication Compliance", "Patient Adherence", "Treatment Compliance", "Therapeutic Compliance", (2) Hypertension; "High Blood Pressure", "Hypertensive Patients", "Elevated Blood Pressure", and (3) Telemedicine; "Mobile Health", "mHealth", "Telehealth", "eHealth", "mobile applications", "mobile application", "mobile apps" and "mobile app".

Data management

All citations of the selected literature and the duplicate records were managed using Mendeley.

Selection process

Two authors conducted the screening process based on the inclusion and exclusion criteria. The selected articles were then downloaded in full text for inclusion in the systematic review. HN, HA initially evaluated the titles and abstracts by enlisting the search results using Microsoft Excel to exclude irrelevant studies. Following this, HN, HA and AR examined the full-text articles of the remaining studies based on the eligibility criteria. Discourse between the authors was done to reach a consensus on which articles be included in the paper.

Quality assessment

Two authors independently conducted a quality assessment of the chosen journals, engaging in discussions to achieve consensus. The evaluation of bias risk adhered to the guidelines outlined in the Mixed Methods Appraisal Tool (MMAT) version 2018. This tool can appraise quantitative non-randomised and randomised controlled trials by assessing five criteria for methodological quality.

Three response options "Yes," "No," and "Can't tell" (see Appendix) were used to indicate whether the criteria are fulfilled, not met, or if there is insufficient information in the paper. "Yes" responses to ≤2, 3, and ≥4 of the questions were classified as low, moderate and high quality respectively. An overall summary was created utilising Risk-of-Bias Visualisation (robvis) (McGuinness & Higgins, 2021).

Data extraction

HN and AR independently carried out data extraction, covering study characteristics and outcomes of interest. HA validated the extracted data for accuracy and completeness, ensuring the absence of errors or crucial omissions during the extraction. The data were then tabulated covering author, year of publication, location and duration of the study, study design; sample size and mobile application used, adherence measurement method and the outcomes.

Results

Search result and study selection

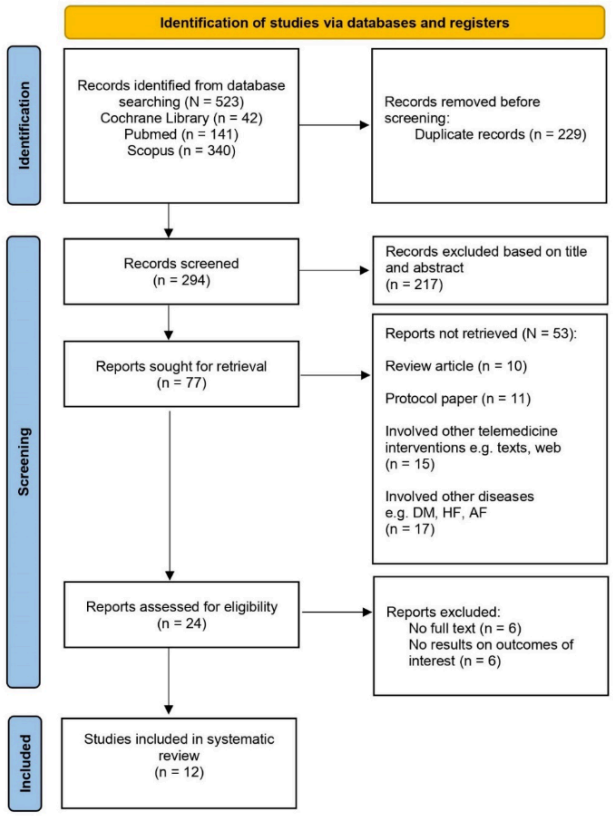
A total of 523 articles were found from the database search, as depicted in Fig. 1. Following the removal of 229 duplicates, 294 records underwent screening based on titles and abstracts. Fifty-three studies were not retrieved for reasons outlined in Fig. 1, and 77 were actively sought through manual searching. Subsequently, 24 articles underwent further assessment for eligibility, with 12 articles ultimately selected following the eligibility criteria. Twelve articles not included were due to unavailability of full text (n=6) and lack of primary results on any relevant outcome (n=6).

Risk of bias and quality assessment

All the studies incorporated in the analysis exhibited moderate to high quality, and the majority demonstrated a low risk of bias, as depicted in Tables 1 and 2.

Characteristics and design of included studies

Table 3 provides an overview of the characteristics of the studies incorporated in this analysis. All studies were published within the past decade from 2013 to 2023. The research was conducted in seven different countries, with almost half of the studies reporting data from the USA (Chandler et al., 2019; Morawski et al., 2018; Patel et al., 2013; Persell et al., 2020; Zha et al., 2020). Five studies originated from Palestine (Abu-El-Noor et al., 2021), Brazil (Volpi et al., 2021), Georgia (Manigault et al., 2020), Kazakhstan (Nurakysh et al., 2022) and Spain (Márquez Contreras et al., 2019), respectively and



*DM: diabetes mellitus; HF: heart failure; AF: atrial fibrillation

Fig. 1: Article Review Process

Table 1: Risk of bias for RCT

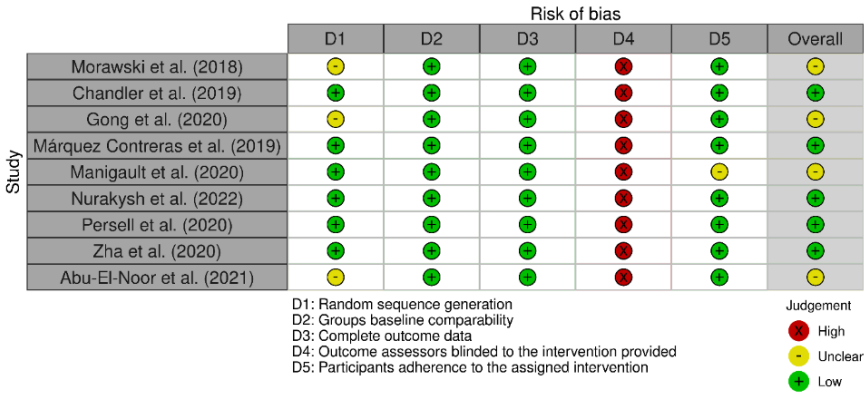
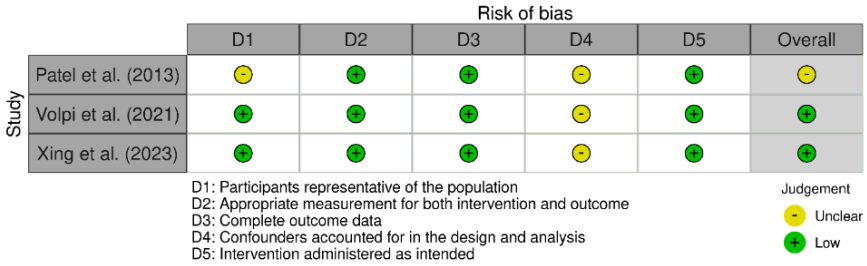


Table 2: Risk of bias for non-RCT



two studies were conducted in China (Gong et al., 2020; Xing et al., 2023). All but three studies are randomised controlled trials.

Participant Characteristics

The collective sample size of the studies involved 8,154 individuals diagnosed with hypertension, ranging from 30 to 5,937 participants in a study. Participants' mean age ranged from 44 (Manigault et al., 2020) to 62 years (Nurakysh et al., 2022). Six studies included the participants' educational backgrounds ranging from high school graduates or lesser to college graduates or more.

Medication Adherence Assessments

Table 3 illustrates the variability in adherence measures across the studies. The majority used questionnaires, such as Morisky Medication Adherence Scale (Chandler et al., 2019b; Gong et al., 2020; Morawski et al., 2018; Patel et al., 2013), Lebanese Medication Adherence Scale (Nurakysh et al., 2022), Patient Medication Adherence Questionnaire (Persell et al., 2020), Martín-Bayarre-Grau Questionnaire (Volpi et al., 2021), Hill-Bone Compliance to High Blood Pressure Therapy Scale (Abu-El-Noor et al., 2021) and Medication Adherence Self-efficacy Scale (Zha et al., 2020). Other methods include Medication Event Monitoring System (Márquez Contreras et al., 2019), refill history (Manigault et al., 2020) and random forest algorithm (Xing et al., 2023).

Effects on Medication Adherence and Clinical Outcomes

Ten studies demonstrated a statistically significant enhancement in medication adherence within the intervention group (Abu-El-Noor et al., 2021; Chandler et al., 2019; Gong et al., 2020; Márquez Contreras et al., 2019; Morawski et al., 2018; Nurakysh et al., 2022; Patel et al., 2013; Volpi et al., 2021; Xing et al., 2023; Zha et al., 2020). However, there was a notable high level of methodological heterogeneity, as different adherence assessment methods and study durations varied among the studies. Of the nine trials that evaluated health-related outcomes, specifically blood pressure readings (both systolic and diastolic), seven reported significant results, indicating an overall improvement with the intervention in blood pressure control (Chandler et al., 2019; Gong et al., 2020; Márquez Contreras et al., 2019; Morawski et al., 2018; Patel et al., 2013; Xing et al., 2023; Zha et al., 2020).

Characteristics of Mobile App

Table 4 outlines the features of the mobile applications employed. All apps features promote medication adherence as their primary function, through medication reminders, blood pressure tracker, patient education and reminders for appointments and refills. Patients' adherence data and BP readings were stored on the cloud storage as health records for ease of access to associated healthcare providers (Gong et al., 2020; Volpi et al., 2021; Xing et al., 2023; Zha et al., 2020). Six studies had healthcare providers interactive features on the mobile apps interface (Abu-El-Noor et al., 2021; Gong et al., 2020; Manigault et al., 2020; Márquez Contreras et al., 2019; Volpi et al., 2021; Xing et al., 2023).

Discussion

Hypertension continues to pose a global public health challenge, impacting an estimated 80 million adults in the USA and exhibiting a high prevalence in Asia over the past decade (Kim et al., 2016; Mahmood et al., 2021). Following the use of mobile applications to curb this challenge, this review compiles the current literature, highlighting 12 studies from the past decade (2013–2023), to examine the impact of mobile application interventions on medication adherence.

A preferable approach to monitor adherence should be dependable, feasible, straightforward, and reasonably cost-effective. As such, no single method fulfils all these criteria, as each type of drug adherence measurement has advantages and disadvantages (Hamdidouche et al., 2017). Although questionnaires are easy to administer, they often suffer from inaccuracy attributable to patients' behavioural biases. Regardless, its use is effective in large populations and allows clinicians to further counsel patients based on the

Table 3: Characteristics of included studies

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)*	
					Medication Adherence	*BP measurement (mmHg)*
Patel et al. (2013) ***USA*** ***Pilot study*** ***3-month*** ***Pill Phone App***	Mean age: 53 Gender Male: 31% Female: 69% Race African-American: 96% Education General education: 79% College graduate: 17% N = 48	- Dose reminder - Pill-taking history record - Dose intake verification - Potential side effects and drug interactions information	Usual care	MMAS-8	Baseline= 2.0 Post= 3.2 p <0.001	Baseline: 144/89 Post: 135/85 p = 0.006
Morawski et al. (2018) ***USA*** ***RCT*** ***3-month*** ***MedISAFE-BP***	Mean age: 52 Gender Female: 60% Race White: 71.3% Black: 20.6% Other: 8.1%	- Dose reminder - Drug interaction checker - BP tracker	Usual care	MMAS-8	IG: 6.3 CG: 5.7 p=0.001	SBP IG: 140.8 CG: 141.2 p= 0.97

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)* *Medication Adherence*	*BP measurement (mmHg)*
	Education High school or less: 14% College grad: 86% N = 411					
Chandler et al. (2019) ***USA*** ***RCT*** ***9-month*** ***SMASH App***	Mean age: IG: 44.4 ± 7.2 CG: 46.8 ± 8.1 Education High school or less: 71% Partial college grad: 29% Gender Male: 61% Race: Hispanic N = 54	- BP progress log - Daily dose reminder	Usual care	MMAS-8	IG: 9.81 ± 1.31 CG: 6.84 ± 1.52 p<0.001	SBP IG: 121.8 CG: 145.7 p < 0.01
Gong et al. (2020) ***China*** ***RCT*** ***6-month*** ***Yan Fu app***	Mean age: IG: 58.20±7.479 CG: 59.27±7.439	- BP tracker - Medicine and exercise reminder - BP limit alarms - Remote consultations with GP	Usual care	MMAS-8	IG: 3.5% CG: 1.83% p= 0.004	SBP IG: 131.52 CG: 135.27 p< 0.05 DBP

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)* *Medication Adherence*	*BP measurement (mmHg)*
	Gender Male: 53% N = 480	- One-click emergency call				IG: 76.86 CG: 78.44 p< 0.05
Márquez Contreras et al. (2019) ***Spain*** ***RCT*** ***12-month*** ***ALERHTA***	Mean age: 57.5 ± 9.9. Gender Male: 47.9% Female: 52% N = 154	- BP goals - Doctor's advice recorder - Appointments reminder - BP tracker	Usual care	MEMS	IG: 89.4 % CG: 81.31% p <0.01	SBP IG: 132.2 ± 12 CG: 134.4 ± 11 p < 0.001 DBP IG: 78.5 ± 7 CG: 81.4 ± 9 p < 0.01
Zha et al. (2020) ***USA*** ***RCT*** ***6-month*** ***iHealth MyVitals***	Mean age: IG: 48.9 ± 8.0 CG: 55.5 ± 5.20 Gender Female: 83% Race Black: 99% White: 1% N = 30	- BP tracker - Instant feedback feature - BP data cloud storage	Usual care	MASES	IG: 69.17 ± 7.77 CG: 61.00 ± 13.08 p = 0.06	SBP IG: 137.38 ± 4.86 p < 0.05. CG: 140.88 ± 5.01 p = 0.17 DBP IG: 88.08 ± 7.45 CG: 88.10 ± 9.41 p = 0.6

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)*	
					Medication Adherence	*BP measurement (mmHg)*
Abu-El-Noor et al. (2021) ***Palestine*** ***RCT*** ***3-month*** ***Self-developed***	Mean age: IG: 55.4 ±10.9 CG: 57.5 ±11.9 Gender: Male: 36.1% Female 63.9% Education High school or less: 86% Partial college grad: 14% N = 191	- Dose and follow-up appointment reminders - Daily education short messages - BP tracker - Short instruction video	Usual care	Hill–Bone CHBPTS	IG: 11.73 CG: 13.98 p< 0.01	Not mentioned
Manigault et al. (2020) ***Georgia*** ***RCT*** ***3-month*** ***BP-n-Me App***	Mean age: IG: 44.4 ± 7.2 CG: 46.8 ± 8.1 Gender Male: 59% Race African-American: 38% Caucasian: 47% Other: 15% N = 78	- Daily dose reminder - "Call your Pharmacy" button - BP tracker - Health tips tailored to patient's lifestyle	Usual care	Refill history	IG: 0.20 CG: 0.20 p = 0.83	SBP IG: 128 CG: 141 p = .001 DBP IG: 78 p = 0.009 CG: 79 p= .0004

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)* *Medication Adherence*	*BP measurement (mmHg)*
Persell et al. (2020) ***USA*** ***RCT*** ***6-month*** ***HBPM***	Mean age: 59.6 ± 12.4 Gender Female: 61.3% Race Asian: 5.9% Black: 30.7% White: 52.3% Other: 11.1% Education High school or less: 9% Partial college grad: 91% N = 297	- Daily dose reminder - Adherence checker	Usual care	PMAQ	Baseline (78.7) Result (80.6) p=0.99	SBP Result:132.3 ± 15.0 Baseline: 140.6 ± 12.2 p = 0.16 DBP Result: 85.1 ± 9.6 Baseline: 89.4 ± 8.7 p=0.61
Volpi et al. (2021) ***Brazil*** ***Non RCT*** ***3-month*** ***Self-developed***	Mean age: IG: 57.2 ± 7.1 CG: 60.4 ± 10.4 Gender Female: 40% Male: 60%	- BP and BMI record - Risk assessment - Recommendations, alerts, and medication reminders - Cloud storage for remote healthcare monitoring.	Usual care	MBGQ	IG:92% adherent, 8% partially adherent ($p < 0.001$). CG: remained virtually the same ($p \geq 0.999$).	Not mentioned

Study (Country, study setting, duration, mobile app)	*Participants' characteristics*	*Intervention group (mobile apps features)*	*Control group*	*Method of adherence measurement*	*Main outcomes (significance)* *Medication Adherence*	*BP measurement (mmHg)*
	Education High school or less: 84% College grad: 16% N = 49					
Nurakysh et al. (2022) ***Kazakhstan*** ***RCT*** ***12-month*** ***MyTherapy***	Mean age: 62.4 ± 3.9 Gender Female: 29.9% Male: 70.1% N = 425	- Customisable medication intake schedule - Tutorial video and text	Usual care	LMAS-14	IG: 40.3 ± 1.3 CG: 33.6 ± 1.9 p ≤ 0.001	Not mentioned
Xing et al. (2023) ***China*** ***Cohort study*** ***Jan 2014 to December 2021.*** ***Self-developed***	Mean age: 66.2±10.8 Gender Male: 47.6% Female: 52.4%% N = 5937	- Medical record BP level and body weight - Interactive family doctor feature	Usual care	Random forest algorithm	IG: 85.8 p<0.001)	p<0.001

RCT: Randomised controlled trial; IG: Intervention Group; CG: Control Group; Hill–Bone CHBPTS: Hill-Bone Compliance to High Blood Pressure Therapy Scale; MMAS-8: 8-item Morisky Medication Adherence Scale; LMAS-14: 14-item Lebanese Medication Adherence Scale; PMAQ: Patient Medication Adherence Questionnaire; MBGQ: Martín-Bayarre-Grau Questionnaire; MASES: Medication Adherence Self-Efficacy Scale; MEMS: Medication event monitoring systems; SBP: Systolic blood pressure; DBP: Diastolic blood pressure

questionnaires (Pandey et al., 2015). Employing an electronic monitoring approach, enhances participants' awareness of their involvement in a study, potentially influencing adherence behaviour (Márquez Contreras et al., 2019).

The assessment of refill history involved a prospective examination of patients' antihypertensive medication refill records and electronic health records. While this method assumes possession of the medication by the patient, it does not necessarily guarantee actual drug intake (Hamdidouche et al., 2017). The usage of models such as the random forest algorithm performed the best in terms of classification accuracy in medication adherence measurements. Nevertheless, the specificity of the algorithm in question would need careful investigation to avoid overprediction of medication nonadherence, consequently wasting resources for preventative measures (Bohlmann et al., 2021).

The utilised mobile apps exhibited varied functionality, incorporating reminders, educational features, or a combination of both, to enhance medication adherence. While the combined features facilitate the patients toward adherence, it is impractical to attribute the effectiveness of specific apps components or characteristics from these interventions. The use of reminders primarily targets individuals who unintentionally forget to take their medication, aiming to address "unintentional nonadherence."

Five studies found that education level did not affect the outcomes as the majority of the participants were high school graduates or of lesser education background (Abu-El-Noor et al., 2021; Chandler et al., 2019; Morawski et al., 2018; Patel et al., 2013; Volpi et al., 2021). One study consisted of participants from higher education background but had no significant difference in the outcomes ($p > 0.05$) (Persell et al., 2020). This finding shows that participants' adoption and e-skills literacy in using mobile apps are effective irrespective of their literacy levels.

This review indicated that the engagement of healthcare providers (HCPs) in-apps interventions for hypertension care primarily included physicians (Abu-El-Noor et al., 2021; Gong et al., 2020; Márquez Contreras et al., 2019; Volpi et al., 2021; Xing et al., 2023), with one trial reporting pharmacist involvement (Manigault et al., 2020). The lesser involvement of pharmacists in the studies is unexpected as pharmacists' roles in clinical patient-facing within primary care are evolving and widening due to their effectiveness in hypertension management and improvement in hypertensive patients' medication adherence (Khaira et al., 2020). Incorporating HCPs alongside the concurrent use of apps in interventions demands careful consideration, as it could potentially lead to an escalation in HCP workload. However, there is inadequate information to determine whether the associated involvement costs outweigh the observed benefits. Although all applications with HCP involvement demonstrated improvement in medication adherence, no cost-benefit analysis was done.

Strengths and Limitations

This systematic review provides insight into mobile apps interventions' effects on medication adherence in hypertensive patients. It was conducted following an extensive literature search, employing MeSH terms and a consistent eligibility criterion to enhance the likelihood of identifying all pertinent studies. The inclusion of both randomised controlled trials (RCTs) and non-RCTs is noteworthy, and despite study quality not being a basis for exclusion, all included studies were moderate to high quality. This suggests that the review encompassed the most reliable evidence available on the subject.

The inclusion of English language publications only, may lead to the exclusion of other language studies with relevant information. Additionally, the conclusions in this review are drawn from a limited dataset of only 12 studies. The heterogeneity in trial methodologies, apps, and adherence assessment methods made it impractical to calculate precise adherence rates and assess the efficacy of individual components' functionality in mobile apps. Despite the limitations, adhering to established guidelines for synthesis afforded us the optimal chance to derive meaningful insights from the available literature. Consequently, this review offers valuable perspectives that can contribute to the enhancement of hypertension care and management.

Conclusion

Mobile apps intervention enhanced medication adherence in hypertensive patients. However, the impact of specific apps intervention features and their effectiveness remains uncertain, which calls for in-depth analysis of the features involved. Further research is required to investigate the involvement of HCPs in mobile apps interventions regarding cost-effectiveness. Lastly, it is recommended that

future studies adopt a standardised and validated approach for measuring medication adherence, facilitating the comparison of results.

Authors contributions

HN and HA autonomously reviewed titles and abstracts and evaluated the complete texts of all eligible studies. HN and AR independently extracted the data, with HA confirming the accuracy and completeness. HN assessed the risk of bias in each included study. All authors have read and approved of the final manuscript.

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Conflict of interest

All authors declare no conflict of interest for this paper.

Declaration of generative AI and AI-assisted technologies in the writing process

In the creation of this work, generative AI technologies were utilised to enhance clarity and refine grammar. The employment of these tools was intended to improve the quality and efficiency of the writing process while preserving the integrity and originality of the content. All AI-generated output was carefully reviewed, revised, and integrated to ensure alignment with our creative and academic objectives.

References

Abu-El-Noor, N. I. I., Aljeesh, Y. I. I., Bottcher, B., & Abu-El-Noor, M. K. K. (2021). Impact of a mobile phone app on adherence to treatment regimens among hypertensive patients: A randomised clinical trial study. European Journal of Cardiovascular Nursing, 20(5), 428–435. https://doi.org/10.1177/1474515120938235

Beleigoli, A. M., Andrade, A. Q., Cançado, A. G., Paulo, M. N. L., Diniz, M. D. F. H., & Ribeiro, A. L. (2019). Web-based digital health interventions for weight loss and lifestyle habit changes in overweight and obese adults: Systematic review and meta-analysis. Journal of Medical Internet Research, 21(1), 1–10. https://doi.org/10.2196/jmir.9609

Bohlmann, A., Mostafa, J., & Kumar, M. (2021). Machine Learning and Medication Adherence: Scoping Review. JMIRx Med, 2(4), e26993. https://doi.org/10.2196/26993

Chandler, J., Sox, L., Kellam, K., Feder, L., Nemeth, L., & Treiber, F. (2019a). Impact of a culturally tailored mhealth medication regimen self-management program upon blood pressure among hypertensive hispanic adults. International Journal of Environmental Research and Public Health, 16(7). https://doi.org/10.3390/ijerph16071226

Chandler, J., Sox, L., Kellam, K., Feder, L., Nemeth, L., & Treiber, F. (2019b). Impact of a Culturally Tailored mHealth Medication Regimen Self-Management Program upon Blood Pressure among Hypertensive Hispanic Adults. International Journal of Environmental Research and Public Health, 16(7), 1226. https://doi.org/10.3390/ijerph16071226

Cowie MR, Bax J, Bruining N, Cleland JG, Koehler F, Malik M, Pinto F, Van Der Velde E, Vardas P. E-Health: a position statement of the European Society of Cardiology. Eur Heart J. 2016; 37:63–66

Gong, K., Yan, Y.-L., Li, Y., Du, J., Wang, J., Han, Y., Zou, Y., Zou, X.-Y., Huang, H., She, Q., & Roever, L. (2020). Mobile health applications for the management of primary hypertension: A multicenter, randomised, controlled trial. Medicine (United States), 99(16), E19715. https://doi.org/10.1097/MD.0000000000019715

Hamdidouche, I., Jullien, V., Boutouyrie, P., Billaud, E., Azizi, M., & Laurent, S. (2017). Drug adherence in hypertension:

Frommethodological issues to cardiovascular outcomes. Journal of Hypertension, 35(6), 1133–1144. https://doi.org/10.1097/HJH.0000000000001299

Khaira, M., Mathers, A., Benny Gerard, N., & Dolovich, L. (2020). The Evolving Role and Impact of Integrating Pharmacists into Primary Care Teams: Experience from Ontario, Canada. Pharmacy, 8(4), 234. https://doi.org/10.3390/pharmacy8040234

Kim, J. Y., Wineinger, N. E., & Steinhubl, S. R. (2016). The Influence of Wireless Self-Monitoring Program on the Relationship Between Patient Activation and Health Behaviors, Medication Adherence, and Blood Pressure Levels in Hypertensive Patients: A Substudy of a RandomisedControlled Trial. Journal of Medical Internet Research, 18(6), e116. https://doi.org/10.2196/jmir.5429

Kumar, N., Khunger, M., Gupta, A., & Garg, N. (2015). A content analysis of smartphone-based applications for hypertension management. Journal of the American Society of Hypertension, 9(2), 130–136. https://doi.org/10.1016/j.jash.2014.12.001

Ma, Y., Cheng, H. Y., Cheng, L., & Sit, J. W. H. (2019). The effectiveness of electronic health interventions on blood pressure control, self-care behavioural outcomes and psychosocial well-being in patients with hypertension: A systematic review and meta-analysis. International Journal of Nursing Studies, 92, 27–46. https://doi.org/10.1016/j.ijnurstu.2018.11.007

Mahmood, S., Jalal, Z., Hadi, M. A., Khan, T. M., Haque, M. S., & Shah, K. U. (2021). Prevalence of nonadherence to antihypertensive medication in Asia: a systematic review and meta-analysis. International Journal of Clinical Pharmacy, 43(3), 486–501. https://doi.org/10.1007/s11096-021-01236-z

Manigault, K. R., McKinley, D., Patel, S., Truong, C., Nguyen, S., Akil, A., Newsom, L., Murnane, K. S., & Thurston, M. M. (2020). The impact of a <scp>pharmacist-designed</scp> mobile application on blood pressure control and medication adherence in patients with hypertension. JACCP: Journal of The American College of Clinical Pharmacy, 3(7), 1286–1295. https://doi.org/10.1002/jac5.1296

Márquez Contreras, E., Márquez Rivero, S., Rodríguez García, E., López-García-Ramos, L., Carlos Pastoriza Vilas, J., Baldonedo Suárez, A., Gracia Diez, C., Gil Guillén, V., & Martell Claros, N. (2019). Specific hypertension smartphone application to improve medication adherence in hypertension: a cluster-randomised trial. Current Medical Research and Opinion, 35(1), 167–173. https://doi.org/10.1080/03007995.2018.1549026

McGuinness, L. A., & Higgins, J. P. T. (2021). Risk-of-bias VISualisation (robvis): An R package and Shiny web app for visualising risk-of-bias assessments. Research Synthesis Methods, 12(1), 55–61. https://doi.org/https://doi.org/10.1002/jrsm.1411

Mills, K. T., Bundy, J. D., Kelly, T. N., Reed, J., Kearney, P., Reynolds, K., Chen, J., & He, J. (2017). Global disparities of hypertension prevalence and Control: A systematic analysis of population-based studies from 90 countries. Physiology & Behavior, 176(3), 139–148. https://doi.org/10.1161/CIRCULATIONAHA.115.018912.Global

Michalakeas, C., Katsi, V., Soulaidopoulos, S., Dilaveris, P., Vrachatis, D., Lekakis, I., Vlachopoulos, C., Tsioufis, K., & Tousoulis, D. (2020). Mobile phones and applications in the management of patients with arterial hypertension. American journal of cardiovascular disease, 10(4), 419–431.

Morawski, K., Ghazinouri, R., Krumme, A., Lauffenburger, J. C. C., Lu, Z., Durfee, E., Oley, L., Lee, J., Mohta, N., Haff, N., Juusola, J. L. L., & Choudhry, N. K. K. (2018). Association of a smartphone application with medication adherence

and blood pressure control: The MedISAFE-BP randomisedclinical trial. JAMA Internal Medicine, 178(6), 802–809. https://doi.org/10.1001/jamainternmed.2018.0447

Moore, T., J. O. Neher and S. J. A. F. P. Safranek (2011). "Improving medication adherence in patients with comorbidities." 84(7): online-online.

Morrissey, E. C., Casey, M., Glynn, L. G., Walsh, J. C., & Molloy, G. J. (2018). Smartphone apps for improving medication adherence in hypertension: patients' perspectives. Patient Preference and Adherence, Volume 12, 813–822. https://doi.org/10.2147/PPA.S145647

Nurakysh, S., Kurakbayev, K., Kosherbaeva, L., Tazhiyeva, A., Aimakhanova, A., Kulkaeva, G., Asykbaeva, L., Ainabekov, M., Fakhradiyev, I., & Tanabayeva, S. (2022). Evaluation of the Effectiveness of the Mobile Application on Adherence of Patients with Arterial Hypertension. Acta Informatica Medica, 30(1), 18. https://doi.org/10.5455/aim.2022.30.18-24

Pandey, A., Raza, F., Velasco, A., Brinker, S., Ayers, C., Das, S. R., Morisky, D. E., Halm, E. A., & Vongpatanasin, W. (2015). Comparison of Morisky Medication Adherence Scale with therapeutic drug monitoring in apparent treatment–resistant hypertension. Journal of the American Society of Hypertension, 9(6), 420-426.e2. https://doi.org/10.1016/J.JASH.2015.04.004

Patel, S., Jacobus-Kantor, L., Marshall, L., Ritchie, C., Kaplinski, M., Khurana, P. S., & Katz, R. J. (2013). Mobilising your medications: An automated medication reminder application for mobile phones and hypertension medication adherence in a high-risk urban population. Journal of Diabetes Science and Technology, 7(3), 630–639. https://doi.org/10.1177/193229681300700307

Persell, S. D., Peprah, Y. A., Lipiszko, D., Lee, J. Y., Li, J. J., Ciolino, J. D., Karmali, K. N., & Sato, H. (2020). Effect of Home Blood Pressure Monitoring via a Smartphone Hypertension Coaching Application or Tracking Application on Adults with Uncontrolled Hypertension: A Randomised Clinical Trial. JAMA Network Open, 3(3), e200255. https://doi.org/10.1001/jamanetworkopen.2020.0255

Rupert, J. and A. J. A. F. P. Mounsey (2022). "Can Mobile Phone–Based Interventions Improve Adherence to Medication for Primary Prevention of Cardiovascular Disease in Adults?" 105(3): 236-237.

Volpi, S. S., Biduski, D., Bellei, E. A., Tefili, D., McCleary, L., Alves, A. L. S., & De Marchi, A. C. B. (2021). Using a mobile health app to improve patients' adherence to hypertension treatment: a non-randomised clinical trial. PeerJ, 9, e11491. https://doi.org/10.7717/peerj.11491

Xing, F., Guo, Y., Xia, N., Zhang, S., Yin, J., Qin, L., Zhu, C., Gao, Q., Jia, J., Zhao, Y., Qi, Y., & Li, W. (2023). Mobile APP-assisted family physician program for improving blood pressure outcome in hypertensive patients. BMC Primary Care, 24(1). https://doi.org/10.1186/s12875-023-01965-2

Zha, P., Qureshi, R., Porter, S., Chao, Y.-Y., Pacquiao, D., Chase, S., & O'Brien-Richardson, P. (2020). Utilizing a Mobile Health Intervention to Manage Hypertension in an Underserved Community. Western Journal of Nursing Research, 42(3), 201–209. https://doi.org/10.1177/0193945919847937

Appendix A

Table A1: Mixed Methods Appraisal Tool (MMAT), version 2018

Category of study designs	Methodological quality criteria	Responses		
		Yes	*No*	*Can't tell*
Quantitative randomised controlled trials	Is randomisation appropriately performed?			
	Are the groups comparable at baseline?			
	Are there complete outcome data?			
	Are outcome assessors blinded to the intervention provided?			
	Did the participants adhere to the assigned intervention?			
Quantitative non-randomised	Are the participants representative of the target population?			
	Are measurements appropriate regarding both the outcome and intervention?			
	Are there complete outcome data?			
	Are the confounders accounted for in the design and analysis?			
	During the study period, is the intervention administered as intended?			