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RESEARCH ARTICLE

The impact of mHealth application on improving medication adherence and hypertension management: A systematic review of randomised trials

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Abstract

Background: The mobile health (mHealth) application has been used for treating hypertension. However, its effectiveness in enhancing adherence and clinical outcomes in hypertensive patients remains limited. **Objective:** This study aimed to determine the impact of mHealth apps on medication adherence and reduced blood pressure among hypertensive patients. **Method:** A systematic review of randomised controlled trials published in Scopus, PubMed, and ScienceDirect from 2008 to 2022 was conducted. Bibliographies of eligible articles were further reviewed. **Result:** A total of 289 articles were identified, and 24 articles were qualified for inclusion. The mHealth apps improved either medication adherence or reduced blood pressure in seven studies (29%). Eleven studies (46%) showed that it could both increase medication adherence and lower blood pressure significantly. Six studies (25%) reported no improvement in both outcomes. **Conclusion:** There is a piece of evidence that mHealth apps can improve medication adherence and, accordingly reduce blood pressure.

Introduction

Hypertension is a chronic disease that requires long-term treatment (Iqbal & Jamal, 2022). This is why adherence to therapy is critical for patients with hypertension. Medications do not work unless the patients take the medicines as instructed (Kreitzer et al., 2008). Medication adherence is the patient's willingness to follow the doctor's advice as recommended (Vrijens et al., 2012).

The medication adherence model states that a patient is obedient to treatment if the patient perceives the drug being consumed is truly effective and safe, and feels the need to take it (Johnson, 2002). For this reason, drug non-adherence is classified into two categories: intentional and unintentional non-adherence. Forgetting to take medication is an example of unintentional non-adherence. Meanwhile, patients intentionally lowering the dose than instructed or even stopping the use of the medicine as they feel better, is an example of intentional non-adherence (van der Laan et al., 2019).

Non-adherence to treatment may reach 50% in the chronic patients. This has affected the therapeutic goals, in patients with chronic diseases or under long-term treatment (Kleinsinger, 2018). Patients, the health care provider, and the health system have been investigated as the factors contributing to non-adherence to treatment (Brown & Bussell, 2011).

Recent strategies to improve medication adherence are behavioural, educational, and organisational approaches (Dayer et al., 2013). The behavioural approach focuses on changing the patient's behaviour, for example, by raising the patient's awareness to achieve therapeutic goals and modifying the environment that supports the formation of new habits, such as using pill boxes and reminders. The educational approach is to provide important information about drugs and diseases and manage the condition they are suffering from. The organisational approach is an approach that focuses on institutions or organisations in minimising gaps or obstacles experienced by patients concerning continuity of treatment, for example, telephone calls or automatic refill reminders from healthcare providers to patients (Dayer et al., 2013; Haase et al., 2017).

The aforementioned strategies can be delivered using mobile applications and they can be uniquely designed for individual patient's needs. Mobile phones are no longer an exclusive item with many people have been using them daily (Dayer et al., 2013; Linn et al., 2011). Based on data from Statista, as of April 2022, unique mobile phone users reach 67% of the world's total population, and of these mobile phone users, 92.4% are internet users. Some of the main reasons they use the Internet are to search for information in general (60.2%) and find health information and related products (35%) (Digital, 2022). With the development of technology that continues to accelerate today, pharmaceutical scientists can embed their concepts into a technology that can facilitate patients' needs in maintaining medication adherence. There are benefits from the development of such applications: patients will find it easier to manage treatment and disease, reduce the incidence of rehospitalisation, reduce health costs, and reach more people without being constrained by distance and time (Dayer et al., 2013).

In 2017, Haase et al. identified 30 applications and suggested 13 outstanding features that should exist in an application to improve medication adherence. Cucciniello et al. (2021) have also conducted a systematic review of the feature development of the mHealth application in chronic disease management. However, the impact of mobile applications on hypertension management and medication adherence is not known. Therefore, this study aimed to make a systematic review of the impact of mobile applications in increasing medication adherence and reducing blood pressure in hypertension patients.

Methods

Design

A systematic review was carried out following the PRISMA guidelines. The databases were searched: Scopus, PubMed, and ScienceDirect. Searches were conducted on April 24, 2022, within articles from 2008 to 2022.

The search string used through the PubMed database was (mHealth OR "mobile application" OR m-health OR "mobile app" OR "mobile health" OR smartphone) AND (Hypertension OR Hypertensive OR "blood pressure" OR "arterial pressure" OR "arterial hypertension") AND (adherence OR non-adherence OR "medication intake") with filters including range 2008 – 2022, Full text, Randomised Controlled Trial, contained in the title and abstract.

The search string used through Scopus was mHealth OR "mobile application" OR m-health OR "mobile app" OR "mobile health" OR smartphone. Search within results 1: Hypertension OR Hypertensive OR "blood pressure" OR "arterial pressure" OR "arterial hypertension". Search within results 1: adherence OR non-adherence OR "medication intake". Limits to: LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE "English)) AND (LIMIT-TO (SRCTYPE, "j").

The search string used in searches through "ScienceDirect" was (mHealth OR "mobile application" OR m-health OR "mobile app" OR "mobile health" OR smartphone) AND (Hypertension OR Hypertensive) AND Adherence. Refine by: 2008 – 2022, research articles, contained in the title and abstract.

Eligible criteria

Articles were declared eligible if they met the inclusion criteria, as shown in Table I

Table I: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
⇨ Original article and randomised controlled trial	⇨ Only examine the feasibility, usability, and acceptability of apps.
⇨ Articles between 2008 – 2022	⇨ Applications only designed for health workers without patients
⇨ Published in the English language	⇨ Articles for which the full text was not found.
⇨ Reporting blood pressure outcomes and medication adherence	⇨ Reviews, descriptive narratives, study protocols, and proceedings.

Assessment

The article selection process began by identifying articles from the PubMed, Scopus, and ScienceDirect electronic databases. After the papers were identified according to the selected keywords, and duplicate content had been removed, then the title and abstract screening were carried out. The initial screening process was to see if there was sufficient information for this review. Finally, articles that passed the initial screening proceeded to in-depth screening, and each excluded article was explained.

A total of two researchers selected the articles that were being used as review material and carried out using the online Covidence program. A joint discussion was held with the involvement of a third researcher if there was a different opinion regarding an eligible article to decide whether the article was included in the inclusion criteria.

Data extraction

Eligible articles included in the inclusion criteria were extracted based on the author, intervention, follow-up duration, the outcome in medication adherence, and blood pressure. The NVIVO 12 software was used to assist in the data extraction and qualitative analysis process.

Results

A total of 44 articles were found after the article identification process, eliminating duplicate content, and screening titles and abstracts. A full-text screening process finally yielded 24 articles. The PRISMA's flowchart can be seen in Figure 1.

Characteristics of included articles

The largest population included in the articles were patients with hypertension (33.3%) (Bozorgi *et al*., 2021; Chandler *et al*., 2019; Gong *et al*., 2020; Kim *et al*., 2016; Márquez Contreras *et al*., 2019; Morawski *et al*., 2018; Persell *et al*., 2020; Zha *et al*., 2020), while the rest was a combination of hypertension and diabetes (n=4) (Frias *et al*., 2017; Oh *et al*., 2022; Prabhakaran *et al*., 2019; Schoenthaler *et al*., 2020), coronary heart disease (n=4) (Li *et al*., 2022; Ni *et al*., 2018, 2022; Santo *et al*., 2019), strokes (n=3) (Sarfo *et al*., 2018; Sarfo *et al*., 2019; Yan *et al*., 2021), multiple chronic diseases (n=3) (Brath *et al*., 2013; Li *et al*., 2021; Moore, 2013), renal transplant recipient (n=1) (McGillicuddy *et al*., 2013), surgical coronary revascularisation (n=1) (Yu *et al*., 2020). The mean age of patients involved in the study was 46.5 (Chandler *et al*., 2019) -69.4 (Brath *et al*., 2013) years old with a median of 57.6 years old.

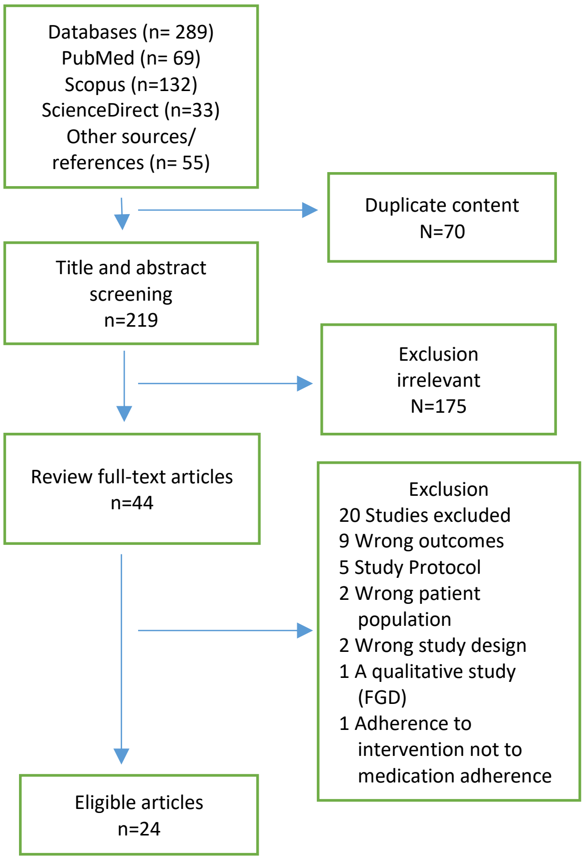

Figure 1: PRISMA flow for literature search and selection

Research on *mHealth* applications for hypertension management and medication adherence continues to increase every five years. From 2013 to 2017, there were six studies (25%) (Brath *et al*., 2013; Frias *et al*., 2017; Kim *et al*., 2016; McGillicuddy *et al*., 2013; Moore, 2013; Sarfo *et al*., 2018), which increased threefold (n=18) between 2018-2022. It was shown that the theme of developing mobile health applications for hypertension management and medication adherence was an important topic and continued to attract researchers from various countries. Most research was conducted in the United States of America (n=9) (Chandler *et al*., 2019; Frias *et al*., 2017; Kim *et al*., 2016; McGillicuddy *et al*., 2013; Moore, 2013; Morawski *et al*., 2018; Persell *et al*., 2020; Schoenthaler *et al*., 2020; Zha *et al*., 2020) and China (n=6) (Gong *et al*., 2020; Li *et al*., 2022; Ni *et al*., 2018, 2022; Yan *et al*., 2021; Yu *et al*., 2020).

From the included papers, the majority used a two-arm RCT study design (n=22), and the rest used a three-arm design (n=2) (Frias *et al*., 2017; Santo *et al.*, 2019). Frias *et al*. (2017) divided the intervention group into two observation groups with different periods (four months and 12 months), while Santo *et al*. (2019) divided the intervention group into two parts based on basic and advanced application. The sample size ranges from 20 (McGillicuddy *et al*., 2013) up to 3324 (Prabhakaran *et al*., 2019) participants. The majority of follow-up intervals were under six months (n=16). Details on this can be found in Table II.

Table II: Characteristics of included studies (n=24)

Study characteristics	n(%)
Population	
Hypertension	8 (33.3)
Hypertension & diabetes	4 (16.7)
Coronary heart disease	4 (16.7)
Stroke	3 (12.5)
Renal transplant recipients	1 (4.2)
Surgical coronary revascularization	1 (4.2)
Multiple chronic diseases	3 (12.5)
Publication year	
2008-2012	0 (0)
2013-2017	6 (25)
2018-2022	18 (75)
Country of study	
United States of America	9 (37.5)
China	6 (25.0)
Ghana	2 (8.3)
Australia	2 (8.3)
Austria	1 (4.2)
India	1 (4.2)
South Korea	1 (4.2)
Iran	1 (4.2)
Spain	1 (4.2)
Study arm	
Two	22 (91.7)
Three	2 (8.3)
Sample size	
<50	5 (20.8)
50-250	13 (54.2)
>250	6 (25.0)
Follow-up interval	
1-3 months	9 (37.5)
4-6 months	7 (29.2)
More than six months	8 (33.3)
FDA approved status	
FDA approved	1 (4.2)
Not yet approved by FDA	23 (95.8)
Operating system	
Android only	5 (20.8)
iOS only	4 (16.7)
Both Android & iOS	6 (25.0)
Neither Android & iOS, prototype	9 (37.5)

Medication adherence and blood pressure outcome

Measuring the level of compliance varies, from those based solely on self-reports to more valid and objective measures and a combination of both. Self-report-based measurement tools used in the included paper include the Voils Medication Non-Adherence Extent Scale (Ni *et al*., 2018, 2022), an eight-item Morisky Medication Adherence Scale (MMAS) (Chandler *et al*., 2019; Kim *et al*., 2016; McGillicuddy *et al*., 2013; Morawski *et al*., 2018; Santo *et al*., 2019; Sarfo *et al*., 2018; Schoenthaler *et al*., 2020), 4-item Morisky Green Levine Scale (Yan *et al*., 2021), Modified Morisky Scale 8 (MMS-8) (Gong *et al*., 2020), 14-item Hill-Bone Scale (range 14–70) (Bozorgi *et al*., 2021), Medication Adherence Self-Efficacy Scale (MASES) (Zha *et al.*, 2020).

Meanwhile, more objective measurement tools include pill count (Brath *et al*., 2013; Li *et al*., 2021), medication possession ratio (MPR) (McGillicuddy *et al*., 2013; Sarfo *et al*., 2019), percentage of prescribed doses that were taken (Frias *et al*., 2017; Li *et al*., 2022; Oh *et al*., 2022; Persell *et al*., 2020; Prabhakaran *et al*., 2019), medication event monitoring system (MEMS) (Márquez Contreras *et al*., 2019; Moore *et al*., 2014; Yu *et al*., 2020), and mobile health-based remote medication Adherence Measurement System (mAMS) (Brath *et al*., 2013). Twelve papers (50%) used self-reported to measure the level of medication adherence, the other eleven (45.8%) used more objective measurements, and only one paper used a combination of both (McGillicuddy *et al*., 2013).

Seventeen papers (Bozorgi *et al*., 2021; Chandler *et al*., 2019; Frias *et al*., 2017; Gong *et al*., 2020; Y. Li *et al*., 2022; Márquez Contreras *et al*., 2019; McGillicuddy et al., 2013; Moore *et al*., 2014; Ni *et al*., 2018, 2022; Oh *et al*., 2022; Persell *et al*., 2020; Sarfo *et al*., 2018;Sarfo *et al*., 2019; Schoenthaler *et al*., 2020; Yan *et al*., 2021; Yu *et al*., 2020) reported results that were linear (directly proportional), in the sense that if the mobile App was able to significantly improve medication adherence, blood pressure outcomes could be managed properly, and vice versa. In more detail, of the seventeen, 11 papers (46%) showed positive results in increasing medication adherence and lowering blood pressure. Meanwhile, six papers (25%) showed that mHealth was not able to increase medication adherence or reduce blood pressure.

Seven papers (29%) reported that the use of mHealth apps has improved either medication adherence or blood pressure reductions. In detail, only three papers (Brath *et al*., 2013; Kim *et al*., 2016; Zha *et al*., 2020) reported that although medication adherence was not significantly different between the intervention and control groups, the blood pressure outcome was still positive. In contrast, four articles (Li *et al*., 2021; Morawski *et al*., 2018; Prabhakaran *et al*., 2019; Santo *et al*., 2019) reported that although medication adherence gave a positive result, the blood pressure outcome showed no significant difference between the intervention and control groups. Details on this can be found in Appendix A.

Discussion

The focus of this systematic review is to determine the mHealth App's effectiveness in managing medication adherence and hypertension. Twenty-four included articles were extracted and analysed in depth. The average age in the included articles is 46.5 (Li *et al*., 2022) – 69.4 (Santo *et al*., 2019) years old, with a median of 57.6 years old. This fact is quite surprising because, in reality, there are many hypertensive patients under 45 years old (CDC, 2021). This is because hypertension is known as a silent killer, and a third of patients do not realise it (Maharjan, 2018).

The increasing number of research on mobile apps for managing medication adherence and hypertension continues to increase. This review shows that there has been a three-fold increase in the number of publications in five years. It is because of the advantages of mobile apps in facilitating self-monitoring coupled with wireless medical peripheral devices, providing tailored practical information (Oh *et al*., 2022), as well as previous systematic review studies stating that the mHealth App is quite promising to improve medication adherence in hypertensive patients (Mikulski *et al*., 2022).

The majority of the follow-up duration in the included papers is less than equal to six months (66.7%). It needs to get more attention in subsequent studies, considering that permanent behavioural changes can only be observed after six months (LaMorte, n.d.). In addition, Becker et al. investigated that the average duration of use of the *mHealth* App was only 23.3 days for users less than 21 years old and 103.9 days for users over 60 years old (Becker *et al*., 2015). Therefore, an approach is needed to increase mHealth usage duration, for example, by providing gamification features to provide rewards and increase engagement to continue using the application. In this systematic review, only two papers included gamification in the application features (Li *et al*., 2021; Schoenthaler *et al*., 2020).

Intervention and outcomes

Discussing hypertension management, the barriers among patients in managing their blood pressure correctly must be known. The two leading factors responsible for uncontrolled hypertension are medication non-adherence and clinical inertia (failure to respond promptly to clinical data) (McGillicuddy *et al*., 2012). Other researchers mentioned that factors that may give rise to poor BP control include: 1) a lack of awareness of hypertension; 2) excessive consumption of alcohol, NaCl, or intake of drugs or 'natural' products that can affect BP (e.g. corticosteroids, nonsteroidal anti-inflammatory drugs, phenylpropanolamine analogs, liquorice and herbal preparations such as Ma Huang, '*herbal ecstasy*', and St John's Wort); 3) poor compliance with recommended lifestyle changes and 4) poor medication adherence (Dusing, 2006).

Dusing (2006) also said that medication non-adherence remains the leading modifiable barrier to blood pressure control. It is also seen in this systematic review that seventeen papers (71%) (Bozorgi *et al*., 2021; Chandler *et al*., 2019; Frias *et al*., 2017; Gong *et al*., 2020; Li *et al*., 2022; Márquez Contreras *et al.*, 2019; McGillicuddy *et al*., 2013; Moore *et al*., 2014; Ni *et al*., 2018, 2022; Oh *et al*., 2022; Persell *et al*., 2020; Sarfo *et al*., 2018; Sarfo *et al*., 2019; Schoenthaler *et al*., 2020; Yan *et al*., 2021; Yu *et al*., 2020) which showed a linear outcome between medication adherence and blood pressure. If the mobile app can significantly increase medication adherence, blood pressure outcomes can be adequately managed, and vice versa.

Non-adherence to antihypertensive medications was noticed in 45% of the subjects studied. A higher proportion of uncontrolled BP (83.7%) was non-adherent to medication (Abegaz *et al*., 2017). Several studies and reviews have posited that forgetting to take medication, knowledge of the disease, perceptions of medication efficacy, lifestyle barriers, and lack of social support are significant contributors to medication non-adherence (Banning, 2009; Chang *et al*., 2021). Intervention models aiming to improve adherence should be emphasised. All included papers (100%) were providing a reminder feature, twenty-two papers (92%) were providing health education/information, and twenty-one papers (88%) were providing a tracking system to anticipate these obstacles.

However, it was found that four articles showed that the mHealth app intervention was able to provide positive outcomes on medication adherence (significant result). Still, blood pressure could not be appropriately controlled (not a significant effect) (Li *et al*., 2021; Morawski *et al*., 2018; Prabhakaran *et al*., 2019; Santo *et al*., 2019). It could be explained as follows: 1) potential bias in self-reporting may have played a role (Prabhakaran *et al*., 2019); 2) the magnitude of medication adherence score changes was likely too small to translate into improvements in blood pressure (Morawski *et al*., 2018; Santo *et al*., 2019). A change of two points in the MMAS-8 has been suggested as the minimum detectable difference for antihypertensive medication adherence (Muntner *et al*., 2011); 3) interventions that focus on instilling motivation and providing ongoing support will be more effective in the management of the chronic disease. Lifestyle factors such as salt reduction, increased physical activity, smoking cessation, and higher intake of fruits and vegetables are as important as medication adherence (Moore *et al*., 2014). Twelve (50%) papers in this systematic review were involving motivational messages in the featured app. The exclusive features were found in the Mediram LIBIT App (Oh *et al*., 2022) and the CollaboRhythm App (Moore *et al*., 2014).

Limitations

This systematic review has various limitations. We only used three databases, so there may be articles that met the inclusion criteria but we could not identify them. We did not perform a quantitative analysis, so we could not estimate the effect size or the strength of the correlation between medication adherence and blood pressure outcomes. Most studies were in short duration (less than or equal to six months).

Conclusion

A mobile health app is a promising approach to improving medication adherence and hypertension management.

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Reference

Abegaz, T.M., Shehab, A., Gebreyohannes, E.A., Bhagavathula, A.S., & Elnour, A.A. (2017). Non-adherence to antihypertensive drugs a systematic review and meta-analysis. *Medicine (United States)*, *Scopus*, **96**. https://doi.org/10.1097/MD.0000000000005641

Banning, M. (2009). A review of interventions used to improve adherence to medication in older people. *International Journal of Nursing Studies*, **46**(11), 1505–1515. https://doi.org/10.1016/j.ijnurstu.2009.03.011

Becker, S., Brandl, C., Meister, S., Nagel, E., Miron-Shatz, T., Mitchell, A., Kribben, A., Albrecht, U.V., & Mertens, A. (2015). Demographic and health-related data of users of a aobile application to support drug adherence is associated with usage duration and intensity. *PLOS ONE*, **10**(1), e0116980. https://doi.org/10.1371/journal.pone.0116980

Bozorgi, A., Hosseini, H., Eftekhar, H., Majdzadeh, R., Yoonessi, A., Ramezankhani, A., Mansouri, M., & Ashoorkhani, M. (2021). The effect of the mobile "blood pressure management application" on hypertension self-management enhancement: A randomized controlled trial. *Trials*, **22**(1), 413. https://doi.org/10.1186/s13063-021-05270-0

Brath, H., Morak, J., Kästenbauer, T., Modre-Osprian, R., Strohner-Kästenbauer, H., Schwarz, M., Kort, W., & Schreier, G. (2013). Mobile health (mHealth) based medication adherence measurement - A pilot trial using electronic blisters in diabetes patients: mHealth based medication adherence measurement system. *British Journal of Clinical Pharmacology*, **76,** 47–55. https://doi.org/10.1111/bcp.12184

Brown, M.T., & Bussell, J.K. (2011). Medication adherence: WHO cares? *Mayo Clinic Proceedings*, **86**(4), 304–314. https://doi.org/10.4065/mcp.2010.0575

CDC. (2021). *Hypertension Prevalence in the U.S. | Million Hearts®*. Centres for Disease Control and Prevention. https://millionhearts.hhs.gov/data-reports/hypertension-prevalence.html

Chandler, J., Sox, L., Kellam, K., Feder, L., Nemeth, L., & Treiber, F. (2019). 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

Chang, S.M., Lu, I.C., Chen, Y.C., Hsuan, C.F., Lin, Y.J., & Chuang, H.Y. (2021). Behavioural Factors Associated with Medication Nonadherence in Patients with Hypertension. *International Journal of Environmental Research and Public Health*, **18**(18), 9614. https://doi.org/10.3390/ijerph18189614

Cucciniello, M., Petracca, F., Ciani, O., & Tarricone, R. (2021). Development features and study characteristics of mobile health apps in the management of chronic conditions: A systematic review of randomised trials. *npj Digital Medicine*, **4**(1), 1. https://doi.org/10.1038/s41746-021-00517-1

Dayer, L., Heldenbrand, S., Anderson, P., Gubbins, P.O., & Martin, B.C. (2013). Smartphone medication adherence apps: Potential benefits to patients and providers. *Journal of the American Pharmacists Association*, **53**(2), 172–181. https://doi.org/10.1331/JAPhA.2013.12202

Digital 2022: *Global Overview Report*. (n.d.). DataReportal – Global Digital Insights. Retrieved May 7, 2022, from https://datareportal.com/reports/digital-2022-global-overview-report

Düsing, R. (2006). Overcoming barriers to effective blood pressure control in patients with hypertension. *Current Medical Research and Opinion*, **22**(8), 1545–1553. https://doi.org/10.1185/030079906X120995

Frias, J., Virdi, N., Raja, P., Kim, Y., Savage, G., & Osterberg, L. (2017). Effectiveness of digital medicines to improve clinical outcomes in patients with uncontrolled hypertension and type 2 diabetes: Prospective, open-label, cluster-randomised pilot clinical trial. *Journal of Medical Internet Research*, **19**(7), e246. https://doi.org/10.2196/jmir.7833

Gong, K., Yan, Y.L., Li, Y., Du, J., Wang, J., Han, Y., Zou, Y., Zou, X., Huang, H. & She, Q. (2020). Mobile health applications for the management of primary hypertension: A multicenter, randomized, controlled trial. *Medicine*, **99**(16), e19715. https://doi.org/10.1097/MD.0000000000019715

Haase, J., Farris, K.B., & Dorsch, M.P. (2017). Mobile Applications to improve medication adherence. *Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association*, **23**(2), 75–79. https://doi.org/10.1089/tmj.2015.0227

Iqbal, A.M. & Jamal, S.F. (2022). Essential hypertension. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK539859/

Johnson, M.J. (2002). The Medication adherence model: A guide for assessing medication taking. *Research and Theory for Nursing Practice*, **16**(3), 179–192. https://doi.org/10.1891/rtnp.16.3.179.53008

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 randomized Controlled Trial. *Journal of Medical Internet Research*, **18**(6), e116 https://doi.org/10.2196/jmir.5429

Kleinsinger, F. (2018). The unmet challenge of medication nonadherence. *The Permanente Journal*, **22**, 18–033. https://doi.org/10.7812/TPP/18-033

Kreitzer, M.J., Sierpina, V.S., & Lawson, K. (2008). Health coaching: Innovative education and clinical programs emerging. *Explore (New York, N.Y.)*, **4**(2), 154–155. https://doi.org/10.1016/j.explore.2007.12.007

LaMorte, W. W. (n.d.). *The transtheoretical model (Stages of Change)*. Retrieved May 20, 2022, from https://sphweb.bumc.bu.edu/otlt/mph-modules/sb/behavioralchangetheories/behavioralchangetheories6.html

Li, A., Del Olmo, M.G., Fong, M., Sim, K., Lymer, S.J., Cunich, M., & Caterson, I. (2021). Effect of a smartphone application (Perx) on medication adherence and clinical outcomes: A 12-month randomised controlled trial. *BMJ Open*, **11**(8), e047041. https://doi.org/10.1136/bmjopen-2020-047041

Li, Y., Gong, Y., Zheng, B., Fan, F., Yi, T., Zheng, Y., He, P., Fang, J., Jia, J., Zhu, Q., Jiang, J., & Huo, Y. (2022). Effects on adherence to a mobile app–based self-management digital therapeutics among patients with coronary heart disease: Pilot randomised controlled Trial. *JMIR MHealth and UHealth*, **10**(2), e32251. https://doi.org/10.2196/32251

Linn, A.J., Vervloet, M., van Dijk, L., Smit, E.G. & Van Weert, J.C.M. (2011). Effects of eHealth interventions on medication adherence: A systematic review of the literature. *Journal of Medical Internet Research*, **13**(4), e103. https://doi.org/10.2196/jmir.1738

Maharjan, B. (2018). Prevalence and awareness of hypertension among Adults and its related risk factors. *Journal of Nepal Health Research Council*, **15**(3), 242–246. https://doi.org/10.3126/jnhrc.v15i3.18848

Márquez C.E., Márquez R.S., Rodríguez, G.E., López-García-Ramos, L., Carlos Pastoriza Vilas, J., Baldonedo Suárez, A., Gracia Diez, C., Gil Guillén, V., Martell Claros, N., & Compliance Group of Spanish Society of Hypertension (SEH-LELHA). (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

McGillicuddy, J.W., Gregoski, M.J., Brunner-Jackson, B.M., Weiland, A.K., Patel, S.K., Rock, R.A., Treiber, E.M., Davidson, L.K. & Treiber, F.A. (2012). Facilitating medication adherence and eliminating therapeutic inertia using wireless technology: Proof of concept findings with uncontrolled hypertensives and kidney transplant recipients. *Proceedings of the Conference on Wireless Health*, **12**, 1–9 https://doi.org/10.1145/2448096.2448108

McGillicuddy, J.W., Gregoski, M.J., Weiland, A.K., Rock, R.A., Brunner-Jackson, B.M., Patel, S.K., Thomas, B.S., Taber, D.J., Chavin, K.D., Baliga, P.K., & Treiber, F.A. (2013). Mobile health medication adherence and blood pressure control in renal transplant recipients: A proof-of-concept randomized controlled trial. *JMIR Research Protocols*, **2**(2), e32. https://doi.org/10.2196/resprot.2633

Mikulski, B.S., Bellei, E.A., Biduski, D., & De Marchi, A.C.B. (2022). Mobile health applications and medication adherence of patients with hypertension: A systematic review and meta-analysis. *American Journal of Preventive Medicine*, **62**(4), 626–634. https://doi.org/10.1016/j.amepre.2021.11.003

Moore, J.O. (2013). *Technology-Supported Apprenticeship in the Management of Chronic Disease*. **93**.

Moore, J.O., Marshall, M.A., Judge, D.C., Moss, F.H., Gilroy, S.J., Crocker, J.B., & Zusman, R.M. (2014). Technology-supported apprenticeship in the management of hypertension: A randomised controlled trial. *Journal of Clinical Outcomes Management*, **21**(3), 110–112.

Morawski, K., Ghazinouri, R., Krumme, A., Lauffenburger, J. C., Lu, Z., Durfee, E., Oley, L., Lee, J., Mohta, N., Haff, N., Juusola, J.L., & Choudhry, N.K. (2018). Association of a smartphone application with medication adherence and blood pressure control: The MedISAFE-BP Randomized Clinical Trial. *JAMA Internal Medicine*, **178**(6), 802. https://doi.org/10.1001/jamainternmed.2018.0447

Muntner, P., Joyce, C., Holt, E., He, J., Morisky, D., Webber, L. S. & Krousel-Wood, M. (2011). Defining the minimal detectable change in scores on the eight-item morisky medication adherence scale. *Annals of Pharmacotherapy*, **45**(5), 569–575. https://doi.org/10.1345/aph.1P677

Ni, Z., Liu, C., Wu, B., Yang, Q., Douglas, C., & Shaw, R.J. (2018). A mHealth intervention to improve medication adherence among patients with coronary heart disease in China: Development of an intervention. *International Journal of Nursing Sciences*, **5**(4), 322–330. https://doi.org/10.1016/j.ijnss.2018.09.003

Ni, Z., Wu, B., Yang, Q., Yan, L.L., Liu, C., & Shaw, R.J. (2022). A mHealth intervention to improve medication adherence and health outcomes among patients with coronary heart disease: Randomized controlled trial. *Journal of Medical Internet Research*, **24**(3), e27202. https://doi.org/10.2196/27202

Oh, S.W., Kim, K.K., Kim, S.S., Park, S.K. & Park, S. (2022). Effect of an integrative mobile health Intervention in Patients With Hypertension and Diabetes: Crossover Study. *JMIR MHealth and UHealth*, **10**(1), e27192. https://doi.org/10.2196/27192

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 randomized clinical trial. *JAMA Network Open*, **3**(3), e200255. https://doi.org/10.1001/jamanetworkopen.2020.0255

Prabhakaran, D., Jha, D., Prieto-Merino, D., Roy, A., Singh, K., Ajay, V. S., Jindal, D., Gupta, P., Kondal, D., Goenka, S., Jacob, P., Singh, R., Kumar, B.G.P., Perel, P., Tandon, N., Patel, V., Venkat, C., Ram, S., Saxena, S., & Sharma, M. (2019). Effectiveness of an mHealth-based electronic decision support system for integrated management of chronic conditions in primary care: The mWellcare cluster-randomized controlled trial. *Circulation*, **139**(3), 380–391. https://doi.org/10.1161/CIRCULATIONAHA.118.038192

Santo, K., Singleton, A., Rogers, K., Thiagalingam, A., Chalmers, J., Chow, C.K. & Redfern, J. (2019). Medication reminder applications to improve adherence in coronary heart disease: A randomized clinical trial. *Heart*, **105**(4), 323–329. https://doi.org/10.1136/heartjnl-2018-313479

Sarfo, F.S., Treiber, F., Gebregziabher, M., Adamu, S., Nichols, M., Singh, A., Obese, V., Sarfo-Kantanka, O., Sakyi, A., Adu-Darko, N., Tagge, R., Agyei-Frimpong, M., Kwarteng, N., Badu, E., Mensah, N., Ampofo, M., Jenkins, C., Ovbiagele, B., & on behalf of PINGS Team. (2019). Phone-based intervention for blood pressure control among Ghanaian stroke survivors: A pilot randomized controlled trial. *International Journal of Stroke*, **14**(6), 630–638. https://doi.org/10.1177/1747493018816423

Sarfo, F., Treiber, F., Gebregziabher, M., Adamu, S., Patel, S., Nichols, M., Awuah, D., Sakyi, A., Adu-Darko, N., Singh, A., Tagge, R., Carolyn, J., & Ovbiagele, B. (2018). PINGS (Phone-based intervention under nurse guidance after stroke): Interim results of a pilot randomized controlled trial. *Stroke*, **49**(1), 236–239. https://doi.org/10.1161/STROKEAHA.117.019591

Schoenthaler, A., Leon, M., Butler, M., Steinhaeuser, K., & Wardzinski, W. (2020). Development and evaluation of a tailored mobile health intervention to improve medication adherence in black patients with uncontrolled hypertension and type 2 diabetes: Pilot randomized feasibility Trial. *JMIR MHealth and UHealth*, **8**(9), e17135. https://doi.org/10.2196/17135

van der Laan, D.M., Elders, P.J.M., Boons, C.C.L.M., Nijpels, G., & Hugtenburg, J.G. (2019). Factors associated with nonadherence to cardiovascular medications: A cross-sectional Study. *Journal of Cardiovascular Nursing*, **34**(4), 344–352. https://doi.org/10.1097/JCN.0000000000000582

Vrijens, B., De Geest, S., Hughes, D.A., Przemyslaw, K., Demonceau, J., Ruppar, T., Dobbels, F., Fargher, E., Morrison, V., Lewek, P., Matyjaszczyk, M., Mshelia, C., Clyne, W., Aronson, J.K., & Urquhart, J. (2012). A new taxonomy for describing and defining adherence to medications. *British Journal of Clinical Pharmacology*, **73**(5), 691–705. https://doi.org/10.1111/j.1365-2125.2012.04167.x

Yan, L.L., Gong, E., Gu, W., Turner, E.L., Gallis, J.A., Zhou, Y., Li, Z., McCormack, K.E., Xu, L.Q., Bettger, J.P., Tang, S., Wang, Y., & Oldenburg, B. (2021). Effectiveness of a primary care-based integrated mobile health intervention for stroke management in rural China (SINEMA): A cluster-randomised controlled trial. *PLOS Medicine*, **18**(4), e1003582. https://doi.org/10.1371/journal.pmed.1003582

Yu, C., Liu, C., Du, J., Liu, H., Zhang, H., Zhao, Y., Yang, L., Li, X., Li, J., Wang, J., Wang, H., Liu, Z., Rao, C., & Zheng, Z. (2020). Smartphone-based application to improve medication adherence in patients after surgical coronary revascularization. *American Heart Journal*, **228**, 17–26. https://doi.org/10.1016/j.ahj.2020.06.019

Zha, P., Qureshi, R., Porter, S., Chao, Y.Y., Pacquiao, D., Chase, S., & O'Brien-Richardson, P. (2020). Utilising 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: The list of articles assessed in the study

No	Ref.	Intervention	Control	Follow-up duration	Outcome In medication adherence	Outcome In blood pressure
1.	(Ni *et al*., 2018)	Received daily reminders and educational materials.	Only received educational materials every five days.	Thirty days	The difference between the two groups was not statistically significant (t = 1, df = 31, p = 0.33).	The difference in the rate of change in the systolic blood pressure (β = 0.17, p = 0.46) and diastolic blood pressure (β = -0.27, p= 0.17) between the two groups was not statistically significant.
2.	(Ni *et al*., 2022)	Received reminders to take medication and educational materials.	Only received educational Materials.	Ninety days	The mean decrease in medication non-adherence score in the experimental group was greater than the decrease in the control group at 90 days and statistically significant (p < 0.001).	The difference in DBP change between the intervention and control groups was statistically significant at 90 days (p = 0.03). The difference in the change in SBP between the two groups was statistically significant at 90 days (t165=3.12, p = 0.002).
3.	(Morawski *et al*., 2018)	Use the Medisafe app.	Not using the Medisafe App.	Twelve weeks	Mean (SD) adherence increased by 0.4 (1.5) in the intervention arm and remained unchanged among controls (between-group difference, 0.4; 95% CI, 0.1-0.7). Statistically significant (p = 0.01)	There was no statistically significant change in blood pressure between the groups (between-group difference, 0.5mmHg; 95%CI,−3.7 to 2.7 mmHg; p = 0.78)
4.	(Schoenthaler *et al*., 2020)	Tailoring survey, an individualized adherence profile, and a personalized list of interactive adherence-promoting modules.	Tailoring survey and health education videos.	Three months	**no significant** differences between-group (p = 0.50)	SBP (−4.76 mm Hg; p = 0.04) with no statistically significant between-group differences (p = 0.50 and p = 0.10). Decreases in DBP were not significant (−1.97 mm Hg; p = 0.20)
5.	(Li *et al*., 2021)	Use the Perx Apps.	Not access the Perx app.	Twelve months	The significant increase in the odds of adherence 90% was 4.37 times higher (95% CI 1.07 to 17.78; p = 0.040) in the 12^{th} month for the Perx group than the control group.	There were no significant differences in blood pressure between the Perx and control groups over the study period.
6.	(Oh *et al*., 2022)	Use LIBIT and Mediram apps.	Usual care without LIBIT and Mediram.	Three-month, (two-period crossover).	**No significant** difference between groups (p = 0.06).	SBP and DBP were insignificant (p = 0.51; p = 0.51, respectively) between intervention and control.
7.	(Persell *et al*., 2020)	Received a smartphone coaching app to promote home monitoring and behavioural changes associated with hypertension self-management, plus a home blood pressure monitor.	Only received a blood pressure tracking app plus a home blood pressure monitor.	Six months.	**No significant** difference between groups (p = 0.99).	SBP and DBP were not significant (p=0.16; p = 0.61, respectively) between intervention and control.

No	Ref.	Intervention	Control	Follow-up duration	Outcome In medication adherence	Outcome In blood pressure
8.	(Yan *et al.*, 2021)	Provider-side components and patient-facing components and were supported by the SINEMA app.	Usual care. Basic Public Health Services.	Twelve months	Adherence to antihypertensive medicines was statistically significant ($p = 0.039$).	**Statistically significant** BP reduction ($p < 0.001$)
9.	(Prabhakaran *et al.*, 2019)	Use mWellcare App	Not used the mWellcare App	Twelve months	Adherence to medication by participants showed a significant difference between arms.	There was no evidence of the difference between the two arms for systolic blood pressure (Δ=−0.98; 95% CI, 4.64 to 2.67)
10.	(Frias *et al.*, 2017)	Use Digital medicine offering (DMO)	Usual care	Twelve weeks	Medication adherence was 80% while using the digital medicine offering (DMO).	Statistically greater SBP and DBP reduction than usual care.
11.	(Li *et al.*, 2022)	Regular follow-up combined with Digital therapeutics (DTx)	Conventional hospital-based follow-up care.	Twelve months	**Significant** improvement in the percentage of all recommended medications in the intervention group compared with the control group (relative risk [RR] 1.34, 95% CI 1.12-1.61; $p = 0.001$)	The intervention group had a significantly higher proportion of patients achieving blood pressure under control (systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg) (RR 1.45, 95% CI 1.22-1.72; $p < 0.001$)
12.	(Chandler *et al.*, 2019)	Utilised a SMASH app which interfaced with a Bluetooth-enabled BP monitor for BP self-monitoring and an electronic medication tray	Received text messages Including links to PDFs and brief video clips containing healthy Lifestyle tips for attention control.	Nine months	**A significant** difference between arms ($p < 0.001$).	SBP and DBP were significant (all *p*-values < 0.01) between intervention and control.
13.	(Santo *et al.*, 2019)	Use MedApp-CHD App	Usual care, no app	Three months	**A significant** difference between the MedApp-CHD group and usual care (95% CI 0.12 to 0.82, $p = 0.008$)	There was no significant difference between groups for systolic and diastolic blood pressure ($p = 0.773$, $p = 0.592$, respectively)
14.	(Brath *et a*l., 2013)	Use a medication adherence measurement system (mAMS)	Standard medication blisters, routine care, and handwritten medication intake diaries.	Thirteen months	**No significant** difference was found for ramipril ($p = 0.50$)	There was a significant difference between groups for systolic and diastolic blood pressure ($p = 0.02$, $p = 0.0003$, respectively)
15.	(Gong *et al.*, 2020)	Use the "*YanFu*" App	Did not use any mHealth apps	Six months	The medication adherence of the intervention group was significantly higher than that of the control group ($p < 0.05$)	**Significantly** greater systolic blood pressure and diastolic blood pressure reduction than the control group ($p < 0.05$).
16.	(Sarfo *et al.*, 2019)	Received a Blue-toothed BP device and smartphone with an App for monitoring BP measurements and	Received SMS dealing with healthy lifestyle	Nine months	**No statistically significant in the** Medication possession ratio between groups ($p = 0.56$).	The proportion of patients with BP<140/90mmHg was 14/30 (46.7%) in the intervention group versus 12/30 (40.0%) in the

No	Ref.	Intervention	Control	Follow-up duration	Outcome In medication adherence	Outcome In blood pressure
		medication intake under nurse guidance	behaviours but not with medication adherence.		**No statistically significant** in MMAS between groups (*p* = 0.94)	control group, *p* = 0.79. **Not statistically significant**.
17.	(Sarfo *et al*., 2018)	Received a Blue-toothed UA-767Plus BT BP device and smartphone for monitoring and reporting BP measurements and medication intake	Received SMS dealing with healthy lifestyle behaviours but not with medication adherence.	Three months	Medication possession ratio scores at month three were better in the intervention (0.88±0.40) versus the control (0.64±0.45) arm (*p* = 0.03). Statistically significant.	Systolic BP <140 mm Hg at month three was statistically significant between the intervention and control group (*p* = 0.12)
18.	(Yu *et al*., 2020)	Receive medication reminders and Cardiac health education by the smartphone application	standard care	Six months	**No statistically significant** in MMAS between groups (*p* = 1.000)	There were **no significant** differences between groups for systolic and diastolic blood pressure (*p* = 0.826, *p* = 0.878, respectively)
19.	(Márquez *et al*., 2019)	Use ALERHTA App	Usual intervention in High Blood Pressure (HBP)	Twelve months	Daily Adherents were 93.15% and 86.3% in IG and 70.66% and 62.66% in CG after six and 12 months, respectively (*p* < 0.05). Statistically significant.	**A significant difference** between groups for systolic and diastolic blood pressure (*p* < 0.001)
20.	(McGillicuddy *et al*., 2013)	Use SMASK App Prototype	standard care.	Three months	The repeated-measures ANOVA yielded a significant group by time interaction F3,48=11.74, *p* < 0.001	A significant group by time interaction was observed for systolic BP (SBP), F3.51=4.33, *p* = 0.009
21.	(Moore *et al*., 2014)	Use the CollaboRhythm tablet application	Received standard hypertension care	Twelve weeks	All of the subjects had medication adherence between 96 and 100%.	**Significant** decrease in Systolic (*p* = 0.009), but not significant in Diastolic (*p* = 0.07)
22.	(Bozorgi *et al*., 2021)	Received a mobile application-based educational-supportive intervention, along with routine treatment.	Routine treatment	Twenty-four weeks	The treatment adherence score significantly increased by an average of 5.9 (95% CI 5.0–6.7) in the intervention group compared to the control group.	**Significant** decrease in mean arterial pressure (MAP). The mean change over time was 3.4 (95% CI 1.6–5.2).
23.	(Kim *et al*., 2016)	Receiving a wireless monitoring program plus disease management	Standard disease management program	Six months	**No significant** difference between groups (*p* = 0.48)	There was a significant difference between groups for systolic and diastolic blood pressure (*p* = 0.02, *p* = 0.007, respectively)
24.	(Zha *et al*., 2020)	Use the iHealth MyVitals application. plus standard care	standard care	Six months	At six months, no statistical significance between the groups was found (*p* = 0.06)	There was a statistically significant difference in systolic BP over six (*p* = 0.01), but there was no significant change in diastolic BP over six months (*p* = 0.60)