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The Effectiveness of an App-Based Tele-Monitoring Intervention Program in Controlling Blood Pressure in Patients with Hypertension

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ABSTRACT

Hypertension remains one of the leading modifiable risk factors for cardiovascular disease, yet blood pressure (BP) control rates achieved through conventional outpatient follow-up remain persistently low. Mobile health (mHealth) tele-monitoring applications that link home BP measurement with automated feedback and remote clinician support have been proposed as a scalable strategy to strengthen self-management between clinic visits. This study evaluated the effectiveness of an app-based tele-monitoring intervention program on BP control, medication adherence, and self-efficacy among patients with hypertension. A quasi-experimental pretest–posttest design with a non-equivalent control group was used, involving 108 hypertensive patients recruited from primary care settings and randomly allocated to an 8-week app-based tele-monitoring program (n = 54) or usual care (n = 54); 97 participants (48 intervention, 49 control) completed follow-up. The intervention combined daily home BP transmission, automated behavior-change reminders, and weekly nurse tele-feedback. The intervention group showed significantly greater reductions in systolic BP (−18.2 vs. −5.8 mmHg) and diastolic BP (−10.8 vs. −4.3 mmHg) than the control group, alongside greater gains in medication adherence and self-efficacy (all $p < .01$), and a higher proportion achieving BP control (70.8% vs. 34.7%). App-based tele-monitoring produced clinically meaningful improvements in BP control beyond usual care and may be a feasible adjunct to hypertension management in primary care.

Keywords : mHealth; hypertension; self-management

INTRODUCTION

Hypertension continues to be the single most important modifiable risk factor for cardiovascular disease, stroke, and premature mortality worldwide. Global estimates indicate that more than 1.2 billion adults live with hypertension, yet fewer than one in five have their blood pressure (BP) adequately controlled, and the gap is widest in low- and middle-income countries where health system capacity for sustained follow-up is limited. In Indonesia, national health survey data show that hypertension prevalence

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among adults exceeds 34%, while awareness, treatment, and control rates remain far below international targets. This pattern is driven not only by limited access to routine screening but also by the episodic nature of conventional outpatient care, in which patients typically receive feedback on their BP only during infrequent clinic visits, leaving long intervals in which suboptimal medication adherence, lifestyle risk factors, and undetected BP fluctuations go unaddressed.

Self-management has therefore become a central pillar of contemporary hypertension guidelines, which recommend home BP monitoring (HBPM) as a means of improving diagnostic accuracy, engaging patients in their own care, and enabling more timely treatment titration. However, the clinical benefit of HBPM depends heavily on how consistently patients measure their BP, how accurately readings are recorded, and whether the resulting data are actually reviewed and acted upon by a health provider. Paper-based diaries are prone to under-reporting, recall bias, and loss to follow-up, limiting their practical impact. Mobile health (mHealth) applications that automatically capture and transmit BP readings address several of these limitations simultaneously: they reduce recording burden, create a continuous longitudinal dataset, and can trigger structured feedback loops between patients and providers outside the walls of the clinic.

A substantial and rapidly growing body of evidence now supports the effectiveness of app-based interventions for BP control. Meta-analyses of randomized controlled trials have consistently reported that mHealth self-management interventions produce statistically and clinically meaningful reductions in systolic BP compared with usual care, with pooled effects in the range of 3 to 9 mmHg depending on intervention intensity and duration (Kassavou et al., 2021; Motta-Yanac et al., 2024; Siopis et al., 2023). Reviews focusing specifically on smartphone applications have similarly found that BP-lowering effects are strongest when apps combine self-monitoring with active feedback, individualized messaging, or clinician-in-the-loop coaching, rather than passive data logging alone (Abe et al., 2024; Kalagara et al., 2022; Zhou et al., 2024). Automated transmission of home BP data to care teams, in particular, has been shown to enhance both adherence to monitoring schedules and the timeliness of treatment adjustment (Kaihara et al., 2022). Individual trials employing app-based tele-feedback models, such as the SMART-BP trial and the Green Heart application study, have reported superior BP reductions and higher rates of BP control among intervention participants relative to those receiving standard care (Ghavami et al., 2024; Yoon et al., 2025). Digital coaching platforms embedded in primary care workflows have likewise demonstrated pragmatic feasibility and improved control rates when deployed under real-world conditions rather than tightly controlled trial settings (Beger et al., 2025).

Despite this expanding evidence base, important gaps remain that constrain the generalizability of existing findings to routine primary care practice in middle-income settings such as Indonesia. First, the majority of published trials have been conducted in high-income health systems with well-established digital infrastructure and dedicated research teams, which limits inference about

effectiveness in resource-constrained primary care and community health center (Puskesmas) contexts where staffing, connectivity, and patient digital literacy differ considerably (Babatunde et al., 2024; Katz et al., 2024). Second, many previous app-based interventions have relied on self-initiated manual data entry rather than automated home BP transmission, introducing measurement and adherence biases that automated tele-monitoring designs are specifically intended to overcome (Xing et al., 2023). Third, few studies have jointly examined clinical BP outcomes alongside behavioral mediators such as medication adherence and self-efficacy within a single intervention arm, even though behavior change theory suggests these mechanisms are central to sustaining BP improvements beyond the intervention period (Lobo et al., 2023; Polsook & Aungsuroch, 2024). Fourth, evidence from lower-resource and rural settings, while growing, remains comparatively sparse and heterogeneous in intervention design, making it difficult to isolate which combination of tele-monitoring components—automated transmission, reminders, or human tele-feedback—drives observed effects (Calderon-Anyosa et al., 2023; Zhang et al., 2023).

The present study addresses these gaps by evaluating a purpose-built app-based tele-monitoring intervention that integrates three components rarely tested together in a single primary care–based trial: automated daily transmission of home BP readings, algorithm-triggered behavior-change reminders, and structured weekly nurse tele-feedback. This design responds directly to calls in recent reviews for tele-monitoring models that pair automated data capture with an active human feedback loop, rather than self-monitoring alone (Hermansson-Borrebaeck et al., 2025; Niu & Li, 2026; Yang et al., 2026). The novelty of this study lies in its evaluation of this integrated model within a primary care population in Indonesia—a middle-income setting with high hypertension prevalence but limited continuity of provider-led follow-up—and in its simultaneous assessment of clinical (BP), behavioral (medication adherence), and psychological (self-efficacy) outcomes within the same cohort, thereby offering a more comprehensive account of how app-based tele-monitoring translates into improved hypertension control in everyday primary care practice. The findings are intended to inform whether such a program can be feasibly scaled within community health center services as a complement to, rather than a replacement for, existing pharmacological management.

Accordingly, this study aimed to determine the effectiveness of an app-based tele-monitoring intervention program, relative to usual care, in improving BP control, medication adherence, and self-efficacy among patients with hypertension managed in a primary care setting.

METHODOLOGY

Design and Setting

This study used a quasi-experimental pretest–posttest design with a non-equivalent control group, conducted over an 8-week intervention period at two community health centers (Puskesmas) providing routine hypertension services. The design was chosen to approximate a randomized controlled framework while remaining feasible within routine primary care operations, consistent with pragmatic trial approaches used in comparable digital health evaluations (Beger et al., 2025).

Participants

Eligible participants were adults aged 30–70 years with a physician-confirmed diagnosis of essential hypertension, currently prescribed antihypertensive medication, and owning or having regular access to a smartphone. Patients with secondary hypertension, severe cognitive impairment, or unstable comorbid cardiovascular events within the preceding three months were excluded. Of 130 patients assessed for eligibility, 108 met inclusion criteria and were allocated to the intervention (n = 54) or control (n = 54) group; 97 participants (48 intervention, 49 control) completed the 8-week follow-up and were included in the final analysis (Figure 1). Sample size was estimated a priori using a two-sample mean-difference formula for a minimum detectable between-group difference of 5 mmHg in systolic BP, with $\alpha = .05$ and power = .80, informed by effect sizes reported in prior mHealth BP trials (Liu et al., 2022; Motta-Yanac et al., 2024).

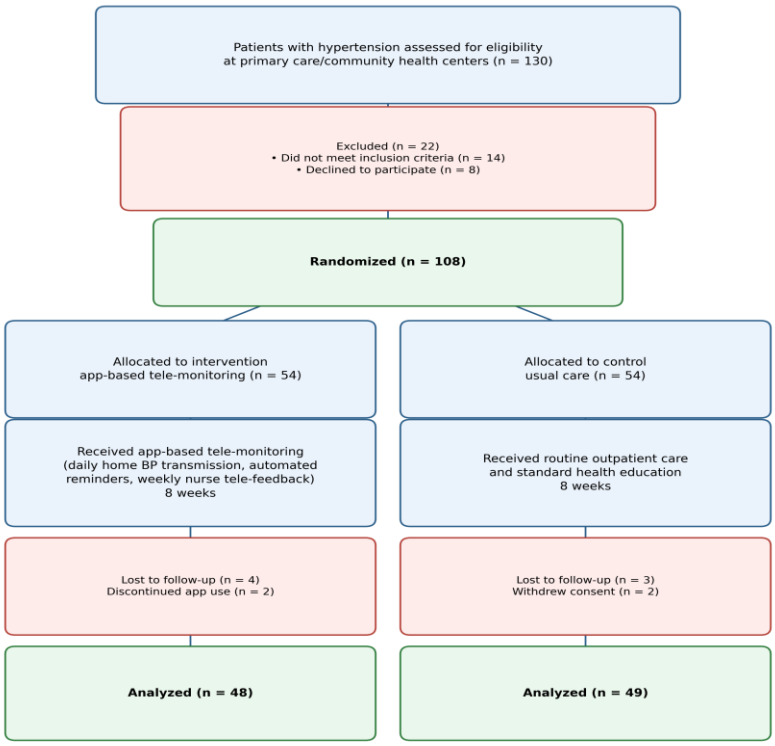


Figure 1. CONSORT flow diagram of participant enrollment, allocation, follow-up, and analysis.

Intervention

Participants in the intervention group received a Bluetooth-enabled home BP monitor linked to a purpose-built mobile application. Each morning and evening, BP readings were captured and automatically transmitted to a cloud-based dashboard accessible to the study nurse. The application delivered three core functions: (1) automated data transmission, eliminating manual logging; (2) algorithm-triggered reminders and brief educational messages addressing medication adherence, dietary sodium intake, and physical activity, tailored to recent readings; and (3) weekly structured tele-feedback calls (10–15 minutes) from a trained nurse, during which readings were reviewed and self-management goals were reinforced. This multicomponent design reflects behavior change techniques identified as most consistently associated with BP improvement in prior syntheses, including self-monitoring, feedback, and goal-setting (Zhou et al., 2024). Control group participants continued routine outpatient care, consisting of scheduled clinic visits and standard verbal health education, without access to the application or automated monitoring.

Outcome Measures

The primary outcome was change in office systolic and diastolic BP from baseline to week 8, measured using a calibrated automatic sphygmomanometer following standardized resting protocols. Secondary outcomes included medication adherence (8-item self-report adherence scale, range 0–8), self-

efficacy for hypertension self-management (10-item scale, range 0–40), and the proportion of participants achieving controlled BP, defined as <140/90 mmHg.

Data Analysis

Baseline comparability between groups was assessed using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. Between-group differences in outcome change from baseline to week 8 were analyzed using analysis of covariance (ANCOVA), adjusting for baseline values, with statistical significance set at $p < .05$. All analyses were conducted on complete cases using per-protocol data from participants who completed the 8-week follow-up.

RESULTS AND DISCUSSION

Baseline Characteristics

Table 1 presents baseline characteristics of the 97 participants who completed follow-up. The intervention and control groups did not differ significantly on age, sex distribution, baseline BP, duration of hypertension, or smartphone ownership (all $p > .05$), indicating adequate comparability between groups at study entry and supporting the internal validity of subsequent between-group comparisons.

Table 1

Baseline Characteristics of Intervention and Control Groups

Characteristic	**Intervention (n = 48)**	**Control (n = 49)**	**p-value**
Age, years, mean (SD)	56.4 (8.1)	57.1 (7.6)	0.641
Female sex, n (%)	29 (60.4)	31 (63.3)	0.766
Baseline SBP, mmHg, mean (SD)	152.3 (9.8)	151.6 (10.2)	0.732
Baseline DBP, mmHg, mean (SD)	94.7 (6.5)	93.9 (7.0)	0.554
Duration of hypertension, years, mean (SD)	6.2 (4.0)	6.5 (4.3)	0.703
Smartphone ownership, n (%)	46 (95.8)	47 (95.9)	0.981

Note. Independent-samples t-test for continuous variables and chi-square test for categorical variables; no significant baseline differences were observed between groups ($p > .05$), indicating successful randomization. SBP = systolic blood pressure; DBP = diastolic blood pressure; SD = standard deviation.

Effect on Blood Pressure and Behavioral Outcomes

As shown in Table 2, the intervention group achieved substantially greater reductions in systolic BP (−18.2 mmHg, from 152.3 to 134.1 mmHg) than the control group (−5.8 mmHg, from 151.6 to 145.8 mmHg), and correspondingly greater reductions in diastolic BP (−10.8 vs. −4.3 mmHg). The proportion of participants achieving controlled BP rose from 18.8% to 70.8% in the intervention group, compared with an increase from 20.4% to 34.7% in the control group. Medication adherence and self-efficacy scores also improved more markedly in the intervention arm. Between-group differences in change scores were statistically significant across all outcomes ($p < .01$).

Table 2

Clinical and Behavioral Outcomes at Baseline and Week 8, by Group

Outcome	Intervention Baseline	Intervention Week 8	Control Baseline	Control Week 8
SBP, mmHg, mean (SD)	152.3 (9.8)	134.1 (8.4)	151.6 (10.2)	145.8 (9.5)
DBP, mmHg, mean (SD)	94.7 (6.5)	83.9 (5.7)	93.9 (7.0)	89.6 (6.4)
Medication adherence score (0–8), mean (SD)	5.1 (1.3)	6.9 (1.1)	5.0 (1.4)	5.4 (1.2)
Self-efficacy score (0–40), mean (SD)	24.6 (5.2)	32.8 (4.6)	24.9 (5.0)	26.7 (4.9)
BP controlled (<140/90 mmHg), n (%)	9 (18.8)	34 (70.8)	10 (20.4)	17 (34.7)

Note. Between-group difference in change from baseline to week 8 was statistically significant for SBP, DBP, medication adherence, self-efficacy, and BP control rate (all $p < .01$), analyzed using analysis of covariance (ANCOVA) adjusting for baseline values. SBP = systolic blood pressure; DBP = diastolic blood pressure; SD = standard deviation.

These findings are consistent with the magnitude of effect reported in recent meta-analyses of mHealth hypertension interventions, which pool systolic BP reductions in the range of 3–9 mmHg relative to control (Kassavou et al., 2021; Motta-Yanac et al., 2024; Siopis et al., 2023). The larger effect observed in this study (12.4 mmHg between-group difference) likely reflects the multicomponent design of the intervention, which combined automated data capture with weekly human tele-feedback rather than relying on self-monitoring or passive app use alone. This pattern mirrors findings from the SMART-BP trial and the Green Heart application study, both of which reported superior BP outcomes when structured feedback was embedded within the digital platform rather than left to patient-initiated review (Ghavami et al., 2024; Yoon et al., 2025). It is also consistent with meta-analytic evidence indicating that automated transmission

of home BP readings, as opposed to manual entry, enhances both measurement fidelity and the likelihood that clinically meaningful trends are identified and acted upon in a timely manner (Kaihara et al., 2022).

The improvement in medication adherence observed in the intervention group aligns with behavior change technique analyses showing that self-monitoring paired with tailored feedback and reminders is among the most effective combinations for sustaining adherence behavior in hypertensive populations (Zhou et al., 2024). Similarly, the marked gain in self-efficacy suggests that regular, personalized tele-feedback may operate not only through direct clinical mechanisms—prompting earlier medication or lifestyle adjustment—but also through psychological pathways, by reinforcing patients' confidence in their capacity to manage their own condition. This dual mechanism has been proposed in prior intervention-mapping work on hypertension apps, which emphasizes that technical functionality alone rarely translates into behavior change without accompanying motivational and educational content (Lobo et al., 2023).

The results also extend prior evidence into a primary care setting characteristic of many middle-income health systems. Unlike several previous trials conducted in well-resourced tertiary or specialty clinics, this study was implemented within routine community health center operations using existing nursing staff, suggesting that comparable effects may be achievable without substantial additional clinical infrastructure. This is an important consideration given documented disparities in digital health effectiveness across resource settings, where feasibility and staff capacity—rather than technology performance alone—often determine real-world impact (Babatunde et al., 2024; Katz et al., 2024). The relatively high rate of smartphone ownership among participants (>95% in both groups) further indicates that digital literacy and device access, frequently cited as barriers to mHealth scale-up in lower-resource settings, may be less limiting in this population than previously assumed, echoing recent Indonesian evidence on mHealth feasibility for hypertension self-management (Widyastuti et al., 2025).

Comparable improvements in self-management outcomes have also been reported in trials combining home telemonitoring with nurse or care-team feedback in other geographic contexts, including rural and low-resource settings, reinforcing the generalizability of the feedback-loop mechanism across diverse populations (Xing et al., 2023; Zhang et al., 2023). At the same time, not all app-based interventions produce comparable effects; reviews have noted considerable heterogeneity in outcomes depending on intervention intensity, duration, and the extent of human involvement, with passive or purely educational applications generally producing smaller effects than those incorporating active feedback loops (Kalagara et al., 2022; Niu & Li, 2026; Yang et al., 2026). This heterogeneity underscores that the specific configuration of tele-monitoring components—rather than app-based delivery per se—is likely the key determinant of clinical effectiveness, a conclusion consistent with the relatively large effect size observed in the present multicomponent design.

Several limitations should be considered when interpreting these findings. The quasi-experimental design without full randomization and blinding introduces potential selection and performance bias, and the 8-week follow-up period does not establish whether observed improvements are sustained over the longer term, a concern also raised in reviews noting inconsistent long-term retention of BP gains after mHealth interventions end (Polsook & Aungsuroch, 2024). The reliance on office BP measurement, rather than fully automated unattended readings, may also introduce measurement variability. Additionally, as the study was implemented at two community health centers with existing digital infrastructure, findings may not generalize to settings with more limited connectivity or nursing capacity. Future research should employ a fully randomized design with longer follow-up, cost-effectiveness analysis, and disaggregated assessment of which intervention components—automated transmission, reminders, or tele-feedback—contribute most strongly to sustained BP control, in order to guide efficient scale-up decisions for primary care systems such as those in Indonesia (Hermansson-Borrebaeck et al., 2025; Yildirim Keskin et al., 2025)..

CONCLUSION

This study found that an app-based tele-monitoring intervention program, combining automated home blood pressure transmission, tailored behavior-change reminders, and weekly nurse tele-feedback, produced significantly greater improvements in blood pressure control, medication adherence, and self-efficacy than usual care among hypertensive patients in a primary care setting. The magnitude of the observed effect, together with the feasibility of implementation using existing community health center staff, suggests that structured app-based tele-monitoring can serve as a practical and scalable adjunct to routine pharmacological management of hypertension. Wider adoption should be informed by future randomized trials assessing long-term sustainability, cost-effectiveness, and the relative contribution of individual intervention components across varied primary care contexts..

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