



Effectiveness of Hybrid Nurse-Led Self-Management Education with a Digital Pocketbook on Medication Adherence and Blood Pressure Control among Patients with Hypertension: A Quasi-Experimental Study

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Abstract

Background: Sustained medication adherence and effective self-management are essential for hypertension control. This study examined the association between hybrid nurse-led self-management education incorporating a Digital Pocketbook and medication adherence and blood pressure outcomes among adults with hypertension. **Methods:** A non-randomized quasi-experimental study with a pretest–posttest control-group design involved 62 adults with hypertension at a primary healthcare facility in Central Java, Indonesia. Participants were allocated to an intervention group ($n = 31$) or control group ($n = 31$). The eight-week intervention combined individualized nurse-led education, a Digital Pocketbook, and weekly WhatsApp follow-up, while controls received routine care. Medication adherence was assessed using the eight-item Morisky Medication Adherence Scale (MMAS-8), and blood pressure was measured using standardized automated procedures. Analysis of covariance (ANCOVA) adjusted for baseline outcome values. **Results:** Compared with controls, the intervention group demonstrated higher medication adherence (adjusted mean difference = 2.18; 95% CI: 1.56–2.80), lower systolic blood pressure (–17.84 mmHg; 95% CI: –22.77 to –12.91), and lower diastolic blood pressure (–11.05 mmHg; 95% CI: –14.34 to –7.76). All comparisons were statistically significant ($p < 0.001$), including after Bonferroni correction. **Conclusions:** Hybrid nurse-led education incorporating a Digital Pocketbook was associated with improved self-reported medication adherence and reduced blood pressure over eight weeks. Larger randomized trials with objective adherence measures and longer follow-up are needed to establish effectiveness and sustainability.

Keywords: Digital Pocketbook; Hypertension; Medication Adherence; Nurse-Led Education; Self-Management

Introduction

More than one billion adults worldwide live with hypertension, yet achieving adequate blood pressure control remains difficult even where effective medication and clinical guidance are available (World

Health Organization, 2023). The consequences of persistent hypertension extend to cardiovascular disease, stroke, kidney disease, and premature mortality (Byrne *et al.*, 2023). Managing this burden can be particularly challenging in low- and middle-income countries, where continuity of chronic disease care may be constrained and uncontrolled hypertension can place additional demands on patients and healthcare services (Niu & Li, 2026).

Patients actions between healthcare visits are an important part of hypertension management. Approximately 30-50% of patients have been reported not to take antihypertensive medication as prescribed (Mahmood *et al.*, 2021). Medication-taking may be affected by limited health literacy, inadequate understanding of hypertension, forgetfulness, misconceptions about long-term treatment, family support, and communication with healthcare professionals (Manortey & Adamaley, 2021). Daily management also extends beyond medication to blood pressure monitoring, dietary practices, physical activity, weight management, smoking cessation, and stress management (Tsai *et al.*, 2025; Zhang *et al.*, 2023). Although education can help patients develop these behaviours, maintaining them outside the healthcare setting remains challenging (Khoiry *et al.*, 2022).

Nurses can address some of these difficulties through individualized education, counselling, reinforcement, and follow-up. Previous nurse-led interventions have reported favorable changes in medication adherence, patient empowerment, and blood pressure outcomes (Bulto *et al.*, 2024; Periyakaruppan *et al.*, 2025). Support concentrated mainly within face-to-face consultations, however, provides fewer opportunities for reinforcement once patients resume their daily routines. Digital educational resources may help bridge this interval by keeping self-management information available outside the healthcare facility (Friska *et al.*, 2022). A digital pocketbook, for example, can be stored on a mobile device and revisited when information or guidance is needed (Hwang & Chang, 2023).

Combining direct nursing support with a simple digital resource may provide a practical way to maintain continuity between clinical encounters. Face-to-face education allows nurses to discuss individual concerns and clarify recommendations, while digital material gives patients an opportunity to return to the information afterwards (Morgado *et al.*, 2024). Remote communication can add further opportunities to discuss difficulties encountered during self-management. Evidence remains limited, however, for a structured programme that brings individualized nurse-led education, a Digital Pocketbook, and regular remote reinforcement together in routine primary healthcare, particularly where simple and accessible digital approaches may be more practical than complex mobile health systems (Aji *et al.*, 2026).

Accordingly, this study examined an eight-week hybrid nurse-led self-management education programme comprising individualized face-to-face education, a Digital Pocketbook, and weekly whatsapp follow-up. The study assessed changes in medication adherence and systolic and diastolic blood pressure among adults with hypertension receiving primary healthcare in Central Java, Indonesia.

Methodology

Study Design

A non-randomized quasi-experimental pretest–posttest control-group design was used. The design enabled comparison of medication adherence and blood pressure before and after the intervention under routine primary healthcare conditions, with participants receiving usual care serving as the comparison group (Andrade, 2021; Nzioki & Korir, 2018). The study was reported with reference to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) Statement. TREND guided the reporting of participant recruitment and allocation, intervention delivery, outcome measurement, statistical procedures, and interpretation of the results (Des Jarlais *et al.*, 2004).

The study was reported in accordance with the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) Statement. The completed TREND checklist is provided as supplementary material. Although the educational approach has been described previously by Aji *et al.*, 2026, the participant-level outcome data and comparative statistical analyses presented in this study have not been published elsewhere.

Study Setting

The study was conducted at a primary healthcare facility in Karanganyar Regency, Central Java, Indonesia, from 12 July 2026 to 12 August 2026. The study period encompassed participant recruitment, baseline assessment, implementation of the nurse-led self-management education programme supported by a digital pocketbook and whatsapp follow-up, and post-intervention outcome assessment. The intervention was integrated into routine hypertension care at the participating primary healthcare facility.

Participants and Group Allocation

A total of 62 adults with hypertension who met the eligibility criteria were enrolled in the study, comprising 31 participants in the intervention group and 31 participants in the control group. Participants were assigned to the intervention or control group based on their geographical area of residence. This allocation procedure was non-randomized; therefore, neither random sequence generation nor allocation concealment was performed. The study consequently employed a non-randomized quasi-experimental pretest–posttest control-group design.

Given the potential for selection bias and geographical differences between groups, baseline demographic and clinical characteristics were compared to assess measured group comparability. To account for potential baseline differences in the primary outcomes, analysis of covariance (ANCOVA) was performed, with the corresponding baseline measurement included as a covariate for each post-intervention outcome. However, adjustment for baseline outcome values could not eliminate potential residual confounding associated with non-randomized group allocation. All 62 participants completed both baseline and post-intervention assessments and were included in the final analysis.

Blinding

Participants and nurses were aware of group assignment because of the nature of the educational programme, and outcome assessment was also conducted without blinding. This was particularly relevant to medication adherence, which was self-reported using the MMAS-8 after intervention participants had received repeated education and follow-up. The potential influence of performance and detection bias was therefore considered when interpreting this outcome.

Sample Size Calculation

The sample requirement was estimated with G*Power version 3.1.9.7 (Faul *et al.*, 2007) for a two-group comparison. The calculation specified a two-tailed α of 0.05, 80% statistical power, and an anticipated effect size of Cohen's $d = 0.80$ based on previous nurse-led hypertension self-management studies. A minimum of 52 participants was required (26 per group). The recruitment target was increased by approximately 20% to allow for possible dropout, resulting in a final target of 62 participants, or 31 per group.

All participants received detailed information regarding the study objectives, procedures, potential benefits, possible risks, confidentiality protection, and their right to withdraw from the study at any time without affecting the healthcare services they received (Parums, 2024). Written informed consent was obtained from all participants before data collection. Participant confidentiality was maintained by assigning coded identifiers, storing data securely, and ensuring that only the research team had access to the study data. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (Kurihara *et al.*, 2024).

Eligibility Criteria

Adults were eligible if they had been diagnosed with primary hypertension, were receiving antihypertensive treatment, could communicate effectively, and provided written informed consent. Participants also needed sufficient access to use the educational materials supplied during the study, including the digital pocketbook. Individuals requiring hospitalization for severe cardiovascular

complications, those with cognitive impairment, or those with another medical condition that could interfere with participation were excluded.

Intervention

Participants in the intervention group received the programme over eight consecutive weeks. Three components were delivered as one package: an individualized face-to-face educational session, access to a digital pocketbook, and weekly whatsapp follow-up. Registered medical-surgical nurses delivered the programme using the same intervention protocol. The content and mode of delivery of each component are presented in Table 1.

Before use in the study, the digital pocketbook was reviewed by professionals with expertise in medical-surgical nursing and cardiovascular care. Their review considered the clinical accuracy and relevance of the hypertension information, clarity and organization of the material, readability, visual presentation, and appropriateness of the self-management recommendations. Comments from the reviewers were incorporated into the version subsequently provided to participants. No quantitative content-validity index or standardized readability assessment was performed; accordingly, this process represented qualitative expert content review rather than formal psychometric validation (Ma et al., 2022).

Participants were contacted through whatsapp once each week during the eight-week programme. These contacts were used to revisit medication and other self-management recommendations, offer motivational support, and discuss problems encountered during hypertension management. In this way, communication with the nursing team continued between face-to-face encounters. Similar remotely delivered nurse-led approaches have been used to extend hypertension self-management support beyond healthcare visits (Hwang & Chang, 2023).

The nurses used common educational materials, structured intervention procedures, and a monitoring checklist to support consistency in programme delivery. Educational and follow-up activities were documented, and the principal investigator provided periodic supervision. These procedures were intended to promote consistent implementation; actual intervention fidelity, however, was not quantified using a formal fidelity measure.

Participants in the control group continued to receive routine hypertension care, including standard medical consultation, prescribed antihypertensive treatment, and routine health education. They did not receive the structured educational programme, digital pocketbook, or scheduled weekly whatsapp follow-up. No attention-matched activity was provided. Consequently, the amount of healthcare-professional contact differed between groups, and this difference was considered when interpreting the findings.

Table 1: Components of the Hybrid Nurse-Led Self-Management Education Programme

Intervention Component	Description
Educational Provider	Registered medical-surgical nurses trained using a standardized intervention protocol
Face-to-Face	One individualized educational session (approximately 60 minutes)
Education	covering hypertension self-management, medication adherence, lifestyle modification, and complication prevention
Educational Material	Digital pocketbook containing evidence-based educational content, illustrations, infographics, medication reminders, self-monitoring records, and lifestyle guidance
Follow-up Strategy	Weekly reinforcement through whatsapp for eight consecutive weeks
Behavioural Reinforcement	Medication reminders, motivational counselling, question-and-answer sessions, and individualized problem-solving support
Intervention Duration	Eight consecutive weeks
Intervention Fidelity	Standardized intervention manual, structured monitoring checklist, and periodic supervision by the principal investigator

Outcome Measures

Medication adherence and blood pressure were assessed at baseline and after completion of the eight-week intervention. Medication adherence was measured using the eight-item Morisky Medication Adherence Scale (MMAS-8). Total scores range from 0 to 8, with higher scores indicating better adherence. Scores were classified as low (<6), medium (6 to <8), or high (8). Previous research has reported satisfactory reliability for the instrument, including a Cronbach's alpha of approximately 0.83 (Sakinah *et al.*, 2024).

The MMAS-8 provided a self-reported measure of medication-taking behavior rather than direct verification of medication consumption. Responses could therefore have been affected by recall or socially desirable reporting, particularly among intervention participants who had repeated contact with nurses. The study did not include pill counts, pharmacy-refill records, or electronic medication monitoring. MMAS-8 findings were consequently interpreted as changes in self-reported medication adherence.

Blood pressure was measured with an Omron HEM-7156 automatic digital sphygmomanometer (Omron Healthcare Co., Ltd., Kyoto, Japan). Participants were asked to avoid smoking, caffeine, and vigorous physical activity for at least 30 minutes before measurement. After five minutes of seated rest, measurements were taken with the participant's back supported, feet flat on the floor, legs uncrossed, and the measured arm supported at heart level. An appropriately sized upper-arm cuff was used. Two readings were obtained 1–2 minutes apart, and their average was recorded for analysis. The same procedure was followed at baseline and after eight weeks for systolic and diastolic blood pressure (McEvoy *et al.*, 2024).

Statistical Analysis

Data were analyzed in IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables are reported as mean $\pm$ standard deviation, while categorical variables are presented as frequencies and percentages (Noorollahi *et al.*, 2025). Normality was examined using the Shapiro–Wilk test and homogeneity of variance using Levene's test.

Baseline continuous characteristics were compared between groups with independent-samples t-tests, whereas categorical characteristics were examined using Chi-square tests. Paired-samples t-tests were used to examine pre–post changes within each group, and independent-samples t-tests were used for initial unadjusted between-group comparisons (Friska *et al.*, 2022).

ANCOVA was then performed separately for medication adherence, systolic blood pressure, and diastolic blood pressure. For each model, the post-intervention measurement was the dependent variable, study group was the fixed factor, and the corresponding baseline measurement was entered as a covariate. The homogeneity-of-regression-slopes assumption was examined through the group $\times$ baseline interaction before each model was fitted. Adjusted mean differences are reported with 95% confidence intervals, p -values, and partial eta squared (η^2p).

The three primary outcomes were examined, $p < 0.0167$ ($0.05/3$) was additionally applied as a Bonferroni-adjusted threshold for the primary between-group comparisons. Cohen's d was used to describe unadjusted within-group changes, whereas η^2p represented the adjusted group effect in the ANCOVA models (Lakens, 2013). Subgroup analyses were not undertaken because the available sample was powered for the overall intervention-control comparison rather than subgroup-specific estimates (Yang *et al.*, 2021).

Ethical Consideration

The study protocol was reviewed and approved by the Health Research Ethics Committee of Universitas Muhammadiyah Semarang, Indonesia with approval no. 098/KEPK-FIKKES/UNIMUS/2026 on 15th January 2026.

Results

A total of 74 individuals were assessed for eligibility. Twelve were excluded before enrollment: seven did not meet the eligibility criteria and five declined participation. The remaining 62 participants entered the study, with 31 in the intervention group and 31 in the control group. No participants were lost during the eight-week follow-up; therefore, outcome data from all 62 participants were included in the final analysis (Figure 1).

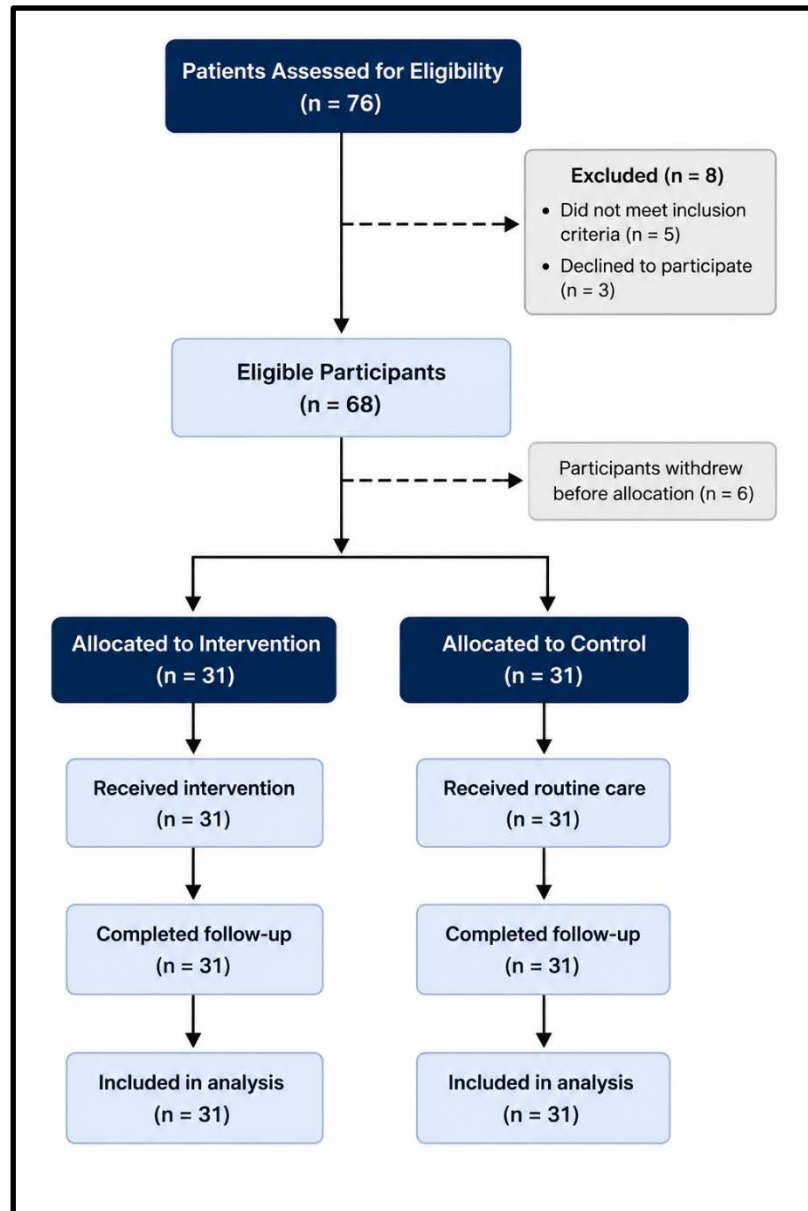


Figure 1: TREND Flow Diagram of Participant Recruitment, Allocation, Follow-up, and Analysis

Figure 1 presents participant progression from eligibility screening through final analysis. All 62 participants who entered the intervention and control groups completed the eight-week follow-up and were included in the analysis, resulting in complete post-allocation outcome data for both groups.

Table 2: Baseline Demographic and Clinical Characteristics of Participants

Variable	Intervention (n = 31)	Control (n = 31)	Statistical Test	p-value
Age (years), Mean $\pm$ SD	56.84 $\pm$ 8.32	57.19 $\pm$ 7.95	Independent t-test	0.866
Male, n (%)	15 (48.4)	16 (51.6)	Chi-square	0.799
Female, n (%)	16 (51.6)	15 (48.4)	-	-

Duration of hypertension (years), Mean $\pm$ SD	6.82 $\pm$ 3.51	6.54 $\pm$ 3.17	Independent <i>t</i> -test	0.743
Body Mass Index (kg/m ²), Mean $\pm$ SD	25.8 $\pm$ 3.2	25.5 $\pm$ 3.4	Independent <i>t</i> -test	0.722
Baseline Medication Adherence (MMAS-8), Mean $\pm$ SD	5.18 $\pm$ 1.07	5.26 $\pm$ 1.14	Independent <i>t</i> -test	0.777
Baseline Systolic Blood Pressure (mmHg), Mean $\pm$ SD	154.61 $\pm$ 10.43	153.92 $\pm$ 9.88	Independent <i>t</i> -test	0.790
Baseline Diastolic Blood Pressure (mmHg), Mean $\pm$ SD	94.84 $\pm$ 6.41	94.29 $\pm$ 6.25	Independent <i>t</i> -test	0.734

Note: Continuous variables were compared using the independent-samples *t*-test, whereas categorical variables were analysed using the Chi-square test. A *p*-value > 0.05 indicates that no statistically significant differences existed between the intervention and control groups at baseline.

The intervention and control groups demonstrated similar measured demographic and clinical characteristics at baseline (Table 2). The mean ages were 56.84 $\pm$ 8.32 years and 57.19 $\pm$ 7.95 years in the intervention and control groups, respectively (*p* = 0.866). Sex distribution, duration of hypertension, and body mass index did not differ significantly between groups (all *p* > 0.05). Baseline medication adherence scores were 5.18 $\pm$ 1.07 in the intervention group and 5.26 $\pm$ 1.14 in the control group (*p* = 0.777). Similarly, baseline systolic blood pressure (154.61 $\pm$ 10.43 vs. 153.92 $\pm$ 9.88 mmHg; *p* = 0.790) and diastolic blood pressure (94.84 $\pm$ 6.41 vs. 94.29 $\pm$ 6.25 mmHg; *p* = 0.734) showed not statistically significant between-group differences. Nevertheless, the absence of statistically significant baseline differences does not establish group equivalence or eliminate potential confounding associated with non-randomized allocation.

Table 3: Assessment of Normality and Homogeneity Assumptions for Primary Outcome Variables

Outcome Variable	Shapiro–Wilk Test (<i>p</i> -value)	Levene's Test (<i>p</i> -value)	Interpretation
Medication Adherence	0.184	0.421	Normally distributed; homogeneous variance
Systolic Blood Pressure	0.132	0.286	Normally distributed; homogeneous variance
Diastolic Blood Pressure	0.217	0.344	Normally distributed; homogeneous variance

Note: A *p*-value > 0.05 in the Shapiro–Wilk test indicates that the data are normally distributed, whereas a *p*-value > 0.05 in Levene's test indicates homogeneity of variance. Therefore, the assumptions required for parametric statistical analyses were satisfied.

Before the intervention, medication adherence and systolic and diastolic blood pressure did not differ significantly between the intervention and control groups (all *p* > 0.05) (Table 2). These findings indicate that the measured primary outcomes were comparable at baseline. The Shapiro–Wilk and Levene's tests indicated that the assumptions of normality and homogeneity of variance were satisfied for all three primary outcomes (Table 3).

Table 4: Changes in Medication Adherence

Group	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Change (95% CI)	<i>t</i> (<i>df</i>)	<i>p</i> -value	Cohen's <i>d</i>
Intervention (n=31)	5.18 $\pm$ 1.07	7.62 $\pm$ 0.74	2.44 (1.71–3.17)	<i>t</i> (30)=6.83	<0.001	1.23
Control (n=31)	5.26 $\pm$ 1.14	5.48 $\pm$ 1.08	0.22 (–0.11–0.55)	<i>t</i> (30) = 1.36	0.184	0.24

Note: Values are presented as mean $\pm$ standard deviation (SD). Mean changes represent the difference between post-intervention and pre-intervention scores. Within-group changes were analysed using paired-samples *t*-tests. CI = confidence interval; *t* = paired-samples *t*-test statistic; *df* = degrees of freedom. Cohen's *d* represents the standardized effect size, interpreted as small (0.20), moderate (0.50), and large ($\geq$ 0.80). Statistical significance was set at *p* < 0.05.

Medication adherence increased substantially in the intervention group, from 5.18 $\pm$ 1.07 at baseline to 7.62 $\pm$ 0.74 after eight weeks (mean change = +2.44, *p* < 0.001; Cohen's *d* = 1.23). The control group showed only a small change over the same period. At post-intervention assessment, medication

adherence was also higher in the intervention group than in the control group (7.62 ± 0.74 vs 5.48 ± 1.08 ; independent-samples *t*-test, $t(60) = 9.10$, $p < 0.001$) (Table 4).

Table 5: Changes in Blood Pressure

Outcome	Group	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Change (95% CI)	<i>t</i> (<i>df</i>)	<i>p</i> -value	Cohen's <i>d</i>
SBP (mmHg)	Intervention (n=31)	154.61 $\pm$ 10.43	132.48 $\pm$ 8.74	-22.13 (-26.91 to -17.35)	$t(30) = -9.46$	<0.001	1.70
SBP (mmHg)	Control (n=31)	153.92 $\pm$ 9.88	149.87 $\pm$ 9.35	-4.05 (-8.72 to 0.62)	$t(30) = -1.77$	0.087	0.32
DBP (mmHg)	Intervention (n=31)	94.84 $\pm$ 6.41	82.16 $\pm$ 5.58	-12.68 (-15.61 to -9.74)	$t(30) = -8.82$	<0.001	1.58
DBP (mmHg)	Control (n=31)	94.29 $\pm$ 6.25	92.84 $\pm$ 5.94	-1.45 (-3.85 to 0.95)	$t(30) = -1.23$	0.228	0.22

Note: Values are presented as mean $\pm$ standard deviation (SD). SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; CI = Confidence Interval; *df* = degrees of freedom. Mean change was calculated as post-intervention minus pre-intervention values; therefore, negative values indicate reductions in blood pressure. Within-group changes were analysed using paired-samples *t*-tests. Cohen's *d* represents the standardized effect size and was interpreted as small (0.20), moderate (0.50), and large (≥ 0.80). Statistical significance was set at $p < 0.05$.

Systolic blood pressure declined markedly in the intervention group during the eight-week period, whereas the reduction in the control group was comparatively small. The within-group change was statistically significant for the intervention group and was accompanied by a large, standardized effect. At post-intervention assessment, systolic blood pressure was significantly lower in the intervention group than in the control group (132.48 ± 8.74 vs 149.87 ± 9.35 mmHg; independent-samples *t*-test, $t(60) = -7.57$, $p < 0.001$). Diastolic blood pressure showed a similar pattern: it declined significantly within the intervention group (mean change = -12.68 mmHg; Cohen's *d* = 1.58) but not within the control group (mean change = -1.45 mmHg; $p = 0.228$), and post-intervention values were significantly lower in the intervention group (82.16 ± 5.58 vs 92.84 ± 5.94 mmHg; $t(60) = -7.30$, $p < 0.001$) (Table 5).

Table 6. Between-Group Comparison of Intervention Effects (Intervention *n* = 31; Control *n* = 31; *N* = 62)

Outcome	Mean Difference (Intervention)	Mean Difference (Control)	Between-Group Difference	95% CI	<i>p</i> -value
Medication Adherence	2.44	0.22	2.22	1.44–3.00	<0.001
Systolic Blood Pressure (mmHg)	-22.13	-4.05	-18.08	-24.63–11.53	<0.001
Diastolic Blood Pressure (mmHg)	-12.68	-1.45	-11.23	-14.94–7.52	<0.001

In table 6, between-group comparisons demonstrated greater changes in all three primary outcomes in the intervention group. The between-group difference was 2.22 points for medication adherence (95% CI: 1.44–3.00), -18.08 mmHg for systolic blood pressure (95% CI: -24.63 to -11.53), and -11.23 mmHg for diastolic blood pressure (95% CI: -14.94 to -7.52), with all comparisons remaining statistically significant at the Bonferroni-adjusted $\alpha = 0.0167$.

Prior to ANCOVA, the homogeneity of regression slopes assumption was examined by testing the interaction between group allocation and the corresponding baseline value for each outcome. No statistically significant group-by-baseline interactions were observed for medication adherence, systolic blood pressure, or diastolic blood pressure (all $p > 0.05$), indicating that the homogeneity of regression slopes assumption was satisfied for all three primary outcomes.

Table 7: ANCOVA Results for Primary Outcomes (Intervention $n = 31$; Control $n = 31$; $N = 62$)

Outcome	Adjusted Mean Difference	95% CI	$F(df1, df2)$	p -value	Partial η^2
Medication Adherence	2.18	1.56-2.80	$F(1, 59) = 48.72$	<0.001	0.45
Systolic Blood Pressure (mmHg)	-17.84	-22.77-12.91	$F(1, 59) = 52.41$	<0.001	0.47
Diastolic Blood Pressure (mmHg)	-11.05	-14.34 - 7.76	$F(1, 59) = 45.26$	<0.001	0.43

Note: ANCOVA was performed for each post-intervention outcome using the corresponding baseline value as a covariate. Adjusted mean differences represent between-group differences in post-intervention outcomes after controlling for baseline measurements. CI = Confidence Interval; df = degrees of freedom; η^2p = partial eta squared. Partial η^2 represents the effect-size estimate for the adjusted group effect and was interpreted as small (0.01), medium (0.06), and large (≥ 0.14).

In Table 7, because three primary outcomes were evaluated, the potential inflation of type I error due to multiple testing was addressed using a Bonferroni-adjusted significance threshold of $\alpha = 0.0167$ (0.05/3) for the primary adjusted comparisons. Exact p -values were reported whenever available; values below 0.001 were reported as $p < 0.001$ rather than $p = 0.000$.

After adjustment for the corresponding baseline values, ANCOVA demonstrated significant between-group effects for medication adherence, $F(1, 59) = 48.72$, $p < 0.001$, $\eta^2p = 0.45$; systolic blood pressure, $F(1, 59) = 52.41$, $p < 0.001$, $\eta^2p = 0.47$; and diastolic blood pressure, $F(1, 59) = 45.26$, $p < 0.001$, $\eta^2p = 0.43$. The adjusted mean differences were 2.18 points (95% CI: 1.56–2.80), –17.84 mmHg (95% CI: –22.77 to –12.91), and –11.05 mmHg (95% CI: –14.34 to –7.76), respectively. All three primary adjusted comparisons remained statistically significant at the Bonferroni-corrected $\alpha = 0.0167$.

Discussion

The present study found that participants receiving Hybrid Nurse-Led Self-Management Education supported by a digital pocketbook demonstrated greater improvements in self-reported medication adherence and systolic and diastolic blood pressure than those receiving routine care. These differences remained statistically significant after adjustment for baseline values. Although the observed effect sizes were large, the findings should be interpreted cautiously because the study used non-randomized allocation, lacked blinding, involved a relatively small single-site sample, and assessed outcomes over only eight weeks (Boima *et al.*, 2024).

The improvement in medication adherence is consistent with previous evidence showing that structured nurse-led interventions can strengthen hypertension self-management and treatment adherence. Nurses can facilitate adherence by providing individualized education, identifying barriers to medication-taking, reinforcing treatment recommendations, and supporting patients in solving problems encountered during daily disease management (Bulto *et al.*, 2024). Digital health interventions may further support these processes by extending access to educational information beyond clinical encounters and facilitating continued engagement between patients and healthcare professionals (Boima *et al.*, 2024). However, direct comparison of effect magnitudes across studies is difficult because intervention components, populations, follow-up periods, outcome measures, and study designs differ (Bulto *et al.*, 2024).

The reductions in systolic and diastolic blood pressure observed in the intervention group were also consistent with evidence supporting nurse-led and digitally supported hypertension management. In the present programme, face-to-face education, the digital pocketbook, and weekly whatsapp follow-up were delivered as an integrated intervention. These components may have provided complementary support: individualized nursing sessions enabled direct discussion of medication and lifestyle barriers, the digital pocketbook allowed participants to revisit educational materials at home, and weekly follow-up provided opportunities for reinforcement and problem solving. However, because the study did not include nurse-led-only or digital-only comparison groups, the independent contribution of each component cannot be determined (Hwang & Chang, 2023).

The magnitude of the observed effects warrants consideration. Large, standardized effect sizes were found for medication adherence and blood pressure, and adjusted analyses remained statistically significant after controlling for baseline measurements. Nevertheless, these estimates should not be interpreted as definitive evidence of intervention efficacy. Non-randomized allocation may have resulted in residual confounding despite comparable measured baseline characteristics, while the absence of blinding and the greater frequency of contact in the intervention group may have influenced participant behavior and outcome reporting. Medication adherence was measured using the self-reported MMAS-8 and may therefore have been affected by recall and social-desirability bias. The observed systolic reduction of approximately 18 mmHg is also larger than the pooled reductions generally reported in systematic reviews of nurse-led and digitally supported interventions (Bulto *et al.*, 2024; Hwang & Chang, 2023), which further supports cautious interpretation and replication. Future randomized studies incorporating objective adherence measures are needed to confirm the magnitude of these effects (Andrade, 2021).

Several features of the intervention provide plausible explanations for the observed short-term improvements. Individualized nurse-led education enabled participants to discuss self-management difficulties directly with trained nurses, while the digital pocketbook provided accessible information that could be reviewed repeatedly outside healthcare visits. Weekly whatsapp contact may also have reinforced medication-taking and lifestyle recommendations throughout the intervention period. Similar digitally supported approaches have been associated with improved engagement and self-management among individuals with hypertension (Upoyo *et al.*, 2024). However, potential mediators such as self-efficacy, knowledge retention, intervention engagement, and digital-pocketbook utilization were not directly measured; therefore, the mechanisms underlying the observed changes cannot be established from the present study.

From a clinical and nursing perspective, the findings suggest that combining individualized nurse-led education with accessible digital materials and remote reinforcement may offer a practical strategy for extending hypertension self-management support beyond routine consultations (Hwang & Chang, 2023; McDonagh *et al.*, 2023). The approach uses resources that are relatively accessible in primary care, particularly smartphone-based communication platforms such as whatsapp (Upoyo *et al.*, 2024). Nevertheless, implementation in other settings should be preceded by evaluation of local feasibility, digital accessibility, nursing workload, patient acceptability, and intervention fidelity (Boima *et al.*, 2024). Standardized nurse training and intervention protocols would also be important to ensure consistent delivery across healthcare settings (Bulto *et al.*, 2024).

The findings should not be interpreted as evidence of long-term cardiovascular benefit or cost-effectiveness. Outcomes were assessed immediately after the eight-week intervention, and the study did not evaluate cardiovascular events, healthcare utilization, intervention costs, or sustainability after structured support ended (Andrade, 2021). Larger multicenter randomized studies with longer follow-up, attention-matched comparison groups, objective medication-adherence measures, and formal implementation and economic evaluations are therefore warranted to determine whether the observed improvements can be replicated, sustained, and feasibly incorporated into routine hypertension care (Niu & Li, 2026).

Limitations

Several features of the study limit the interpretation of its findings. Group assignment was not randomized, leaving the possibility of residual differences between groups despite their comparable measured baseline characteristics. Participants, nurses, and outcome assessment were not blinded, and medication adherence was measured by self-report rather than by an objective indicator. The control group also received no attention-matched activity, while intervention participants had additional contact with nurses through weekly whatsapp follow-up. In addition, the digital pocketbook underwent qualitative expert review but not formal quantitative content validation. Finally, the sample comprised 62 participants from a single primary healthcare setting, and outcomes were measured only through

the end of the eight-week programme. These factors limit generalizability and leave the durability of the observed changes uncertain.

Future Scope

Further evaluation should test the programme under more rigorous and diverse conditions. A multicentre randomized trial with longer follow-up would help determine whether the observed changes can be reproduced across primary care settings and maintained after structured support ends. Objective indicators of medication adherence and an attention-matched comparison condition would strengthen outcome assessment. Multi-arm or factorial designs could additionally separate the contributions of nurse-led education, the digital pocketbook, and remote follow-up. Evaluation of patient engagement, implementation consistency, nursing workload, feasibility, and costs would also be valuable before wider integration into routine primary healthcare.

Conclusion

During the eight-week study period, adults receiving hybrid nurse-led self-management education with a digital pocketbook showed greater improvement in self-reported medication adherence and larger reductions in systolic and diastolic blood pressure than those receiving routine care. The between-group differences remained after adjustment for baseline outcome values. These results support further evaluation of an approach that combines individualized nursing education, reusable digital information, and remote follow-up for hypertension self-management in primary care. Given the non-randomized, single-site design and short follow-up, randomized multicentre studies with objective adherence measures and longer observation are needed before conclusions can be drawn about sustained effectiveness or broader implementation.

CRedit Authorship Contribution Statement

P.T.A.: Conceptualization, methodology, investigation, formal analysis, data curation, visualization, writing - original draft, project administration. **T.B.S. :** Conceptualization, methodology, validation, supervision, writing – review and editing. **C.S.K.:** Formal analysis, validation, visualization, writing – review and editing.

AI Assistance Declaration

Generative artificial intelligence (AI) tools, including ChatGPT (OpenAI), were used during manuscript revision to assist with language refinement, grammatical editing, and improving the clarity and organization of selected sections. The authors critically reviewed and revised all AI-assisted text and independently verified the scientific content, data, statistical results, interpretations, and references. AI tools were not used to generate or alter research data, perform statistical analyses, or make decisions regarding the study findings. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

Conflict of Interest

The authors declare that there are no financial, commercial, institutional, or personal relationships that could be construed as potential conflicts of interest regarding the research, authorship, and publication of this article. The authors affirm that the study was conducted independently and that the findings presented in this manuscript were not influenced by any external interests or organizations.

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