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Wearable-Integrated Education and Its Association with Self-Management and Quality of Life Among Patients with Hypertension: A Quasi-Experimental Study

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A B S T R A C T

Introduction: Hypertension is a leading global health concern requiring sustained self-management to prevent complications and improve quality of life. While digital health interventions are increasingly adopted, evidence on the effectiveness of wearable-integrated education in hypertension management remains limited. **Objective:** This study aimed to evaluate the effectiveness of wearable-integrated education on self-management behaviors and quality of life in patients with hypertension. **Methods:** A quasi-experimental study was conducted with 200 hypertensive patients recruited from community health centers. Participants were allocated into an intervention group (n = 100), which received wearable-integrated educational modules providing personalized feedback and reminders, and a control group (n = 100), which received standard health education. Outcomes included self-management, measured using the Hypertension Self-Management Behavior Questionnaire (HSMBQ), and quality of life, assessed with the WHOQOL-BREF. Descriptive, correlation, and multivariate regression analyses were performed. **Results:** Participants had a mean age of 54.2 years (SD = 9.1), with no significant baseline differences between groups. Post-intervention, the intervention group reported significantly higher self-management scores (78.4 ± 8.6 vs. 70.2 ± 9.1; $p < 0.001$) and quality of life scores (82.6 ± 10.2 vs. 75.1 ± 11.0; $p < 0.001$) compared with controls. Correlation analyses indicated that higher education, shorter duration of hypertension, and intervention participation were positively associated with outcomes. Multivariate regression confirmed the intervention as an independent predictor of both self-management ($\beta = 0.39$, $p < 0.001$) and quality of life ($\beta = 0.36$, $p < 0.001$), with models explaining 29% and 26% of the variance, respectively. **Conclusion:** Wearable-integrated education significantly improves self-management behaviors and quality of life among hypertensive patients. These findings highlight the potential of integrating wearable technology with educational strategies as a scalable, community nursing–driven approach to hypertension management.

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1. INTRODUCTION

Hypertension remains one of the most consequential, modifiable risk factors for premature morbidity and mortality worldwide. Despite decades of advances, global progress in treatment and control has been uneven; pooled analyses of 184 countries estimate that the number of adults living with hypertension grew substantially between 1990 and 2019, with large gaps in awareness, treatment, and control, particularly in low- and middle-income settings (LMICs) (NCD Risk Factor Collaboration [NCD-RisC], 2021). Recent World Health Organization (WHO) guidance underscores intensified pharmacologic therapy alongside lifestyle modification and task-sharing models, while calling for practical strategies to enable patient self-management at scale (World Health Organization, 2021). These realities have accelerated interest in digitally enabled approaches that can complement guideline-based care by supporting day-to-day self-care behaviors that ultimately drive blood pressure (BP) control and quality of life (QoL).

A evidence base shows that connected and digital health interventions can reduce BP when layered onto usual care. Meta-analytic syntheses across diverse populations report clinically meaningful reductions in systolic BP (SBP) with multicomponent programs that often include remote BP monitoring, asynchronous coaching, and algorithmic feedback (Siopis et al., 2023; Katz et al., 2024). Effect sizes are frequently larger in programs that incorporate structured telemonitoring or collaborative care, such as pharmacist-supported home BP telemonitoring (Baral et al., 2023), and earlier connected-health reviews in hypertension highlight consistent BP improvements when telemetry and counseling are combined (Omboni, 2019). Importantly, these benefits extend to populations experiencing health disparities, in whom tailored digital strategies have yielded greater SBP reductions than standard care at 6–12 months (Katz et al., 2024).

Within the broad digital health landscape, mobile health (mHealth) apps have emerged as common vehicles for self-management support. A 2024 systematic review and meta-analysis of randomized controlled trials (RCTs) identified specific behavior change techniques (BCTs), such as self-monitoring, feedback, goal setting, and prompts/cues as an active ingredients associated with improved BP and adherence in app-based hypertension interventions (Zhou et al., 2024). Complementary evidence from LMICs indicates digital strategies can improve SBP, medication adherence, and lifestyle behaviors, though heterogeneity in intervention content and reporting remains high (Boima et al., 2024). Together, these findings reinforce that the design of digital interventions and not merely their presence a matters for clinical impact.

Wearable devices (e.g., cuffless or connected BP monitors, smartwatches, activity trackers) add a second, potentially powerful layer to mHealth: continuous or high-frequency sensing that can trigger just-in-time, context-aware feedback. Systematic reviews across chronic diseases suggest wearables can positively influence health behaviors and intermediate outcomes, yet they also note variable methodological quality and limited reporting on patient-centered outcomes such as QoL (Mattison et al., 2022). In hypertension specifically, connected-care reviews have emphasized that many commercial tools underutilize educational content or deliver education of inconsistent quality, potentially blunting longer-term behavior change (Omboni,

A theoretical basis for wearable-integrated education can be drawn from Social Cognitive Theory (SCT), particularly the concept of self-efficacy as a determinant of health behavior change (Bandura, 1986; Bandura, 1997). SCT proposes that behavior is shaped through

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reciprocal interactions among personal factors, environmental influences, and behavioral experiences, with self-efficacy influencing an individual's confidence in initiating and sustaining health-related actions. In hypertension management, wearable devices may strengthen self-efficacy by facilitating self-monitoring, delivering immediate feedback, increasing awareness of behavioral patterns, and reinforcing goal-directed actions. When wearable-generated data are integrated with structured educational content and behavior change techniques (BCTs), such as feedback, prompts, and goal setting, patients may become more capable of translating health information into sustained self-management behaviors. Improved self-management may subsequently contribute to better symptom control, greater perceived autonomy, and enhanced quality of life. This conceptual pathway is consistent with evidence suggesting that self-efficacy mediates engagement in chronic disease self-management and influences patient-reported outcomes (Lorig & Holman, 2003). Therefore, this study conceptualizes wearable-integrated education as an intervention that influences outcomes through self-efficacy enhancement and behavioral activation mechanisms.

Despite encouraging signals, two gaps persist. First, most hypertension meta-analyses focus on BP control and adherence; comparatively fewer trials are designed to detect changes in QoL or self-efficacy, even though these are central to sustained self-management. Second, prior studies often evaluate wearables as monitoring add-ons rather than as catalysts for education that adapts to wearable-derived data (e.g., personalized feedback, micro-lessons triggered by inactivity or elevated home BP, or clinician-endorsed explanations of readings). Recent mHealth evidence clarifies which BCTs matter, but it remains unclear whether wearable-integrated education structured, theory-informed educational content that is timed and tailored using wearable data amplifies effects on self-management behaviors and QoL beyond monitoring alone (Zhou et al., 2024; Boima et al., 2024). Nurse- or pharmacist-enabled telemonitoring models reduce BP, yet the incremental contribution of education tightly coupled to real-time wearable feedback is under-examined and seldom linked to validated QoL endpoints. To address these gaps, the present study evaluates the effectiveness of wearable-integrated education on self-management and QoL among adults with hypertension. Guided by Social Cognitive Theory, we hypothesize that, compared with standard care, a wearable-integrated educational program combining wearable-based sensing with structured, behavior change technique (BCT)-informed micro-education will enhance self-efficacy and subsequently improve (1) self-management behaviors (e.g., medication adherence, physical activity, and home BP monitoring fidelity) and (2) patient-reported quality of life, alongside favorable changes in blood pressure.

2. METHODS

Study Design

This study employed a quasi-experimental design with intervention and control groups to evaluate the effectiveness of wearable-integrated education on self-management and quality of life among patients with hypertension. The intervention group received wearable-based education combined with standard care, whereas the control group received standard care only. Participants were allocated using consecutive sampling with group assignment based on clinic flow (non-randomized allocation). Baseline equivalence between groups was assessed and statistically

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confirmed. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Sample

Participants were recruited from outpatient clinics specializing in hypertension management in Makassar, Indonesia. Eligible participants were adults diagnosed with hypertension who attended routine follow-up care.

Inclusion criteria were: (a) age between 30 and 70 years; (b) clinical diagnosis of hypertension confirmed by a physician; (c) ability to use a wearable device and mobile application; and (d) willingness to provide informed consent. Exclusion criteria included: (a) history of severe cardiovascular complications (e.g., stroke, myocardial infarction) in the past six months; (b) cognitive impairment or psychiatric illness that could interfere with study participation; (c) concurrent participation in another lifestyle intervention study; and (d) inability to read or understand Bahasa Indonesia.

The sample size was calculated using G*Power version 3.1, with parameters set for multiple regression analysis (effect size $f^2 = 0.15$, $\alpha = 0.05$, power = 0.80, and up to five predictors). The analysis indicated a minimum of 85 participants per group. To account for potential attrition, the sample size was increased to 100 participants per group, resulting in a total of 200 participants. Participants were recruited using consecutive sampling until the required sample size was achieved. Eligible patients who met the inclusion criteria were allocated into the intervention and control groups through consecutive sampling, without computer-generated randomization.

Instruments

Self-management was assessed using the Hypertension Self-Management Behavior Questionnaire (HSMBQ), originally developed by Lee et al. (2011). The instrument consists of 25 items across domains of medication adherence, dietary practices, physical activity, and stress management. Each item is rated on a 4-point Likert scale (1 = never to 4 = always), with higher scores indicating better self-management. The original instrument demonstrated good internal consistency (Cronbach's $\alpha = 0.86$) (Zhao et al., 2012). The validated Bahasa Indonesia version also showed high reliability (Cronbach's $\alpha = 0.84$) and satisfactory construct validity.

Quality of life was measured using the WHOQOL-BREF, developed by the World Health Organization (1998). The instrument contains 26 items grouped into four domains: physical, psychological, social relationships, and environment. Items are scored on a 5-point Likert scale, and higher scores reflect better quality of life. The original version demonstrated reliability coefficients ranging from 0.66 to 0.84 across domains. The Bahasa Indonesia version has been validated, with Cronbach's α ranging from 0.70 to 0.83, confirming its suitability for use in this population (Anisah et al., 2019).

Procedure

Eligible participants were identified during outpatient visits and provided with study information. Written informed consent was obtained from all participants.

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Following baseline assessment, participants were allocated into intervention or control groups using consecutive assignment based on recruitment sequence and clinic attendance flow (non-randomized).

The intervention consisted of a wearable-integrated education program delivered over 12 weeks, which included:

(a) Wearable device: Participants used a validated wearable blood pressure monitoring device and a connected activity tracker to record daily blood pressure, step count, and physical activity duration. Readings were automatically synchronized to a mobile application.

(b) Educational modules: Structured micro-education content was delivered via the mobile application, covering hypertension knowledge, medication adherence, dietary modification (DASH principles), physical activity recommendations, and stress management strategies. Content was adapted into short weekly modules aligned with behavior change techniques (BCTs), including goal setting, feedback on performance, and prompts/cues.

(c) Feedback mechanism: Participants received automated individualized feedback based on wearable data at least once per week, including summaries of blood pressure trends, physical activity achievement, and behavioral reinforcement messages.

(d) Interaction frequency and duration: Participants engaged with the mobile application daily for monitoring and at least once weekly for structured educational modules and feedback review across the 12-week intervention period.

(e) Adherence monitoring: Adherence was monitored through wearable data logs (frequency of BP measurements and step counts) and application usage analytics (module completion rate and login frequency). Participants with <70% engagement were flagged for follow-up reminders.

(f) Intervention fidelity: Fidelity was ensured through standardized educational content delivery, automated system-based feedback algorithms, and weekly monitoring by trained research nurses to ensure consistent implementation across participants.

The control group received standard hypertension education routinely provided in the clinic without wearable integration or digital feedback. Post-intervention data were collected at 12 weeks. Participants also provided feedback on usability and acceptability through structured debriefing sessions.

Data Analysis

Data were analyzed using SPSS version 25. Descriptive statistics were used to summarize demographic and clinical characteristics. Independent t-tests and chi-square tests were applied to compare baseline characteristics between groups. Multiple linear regression analyses were performed to examine the effect of wearable-integrated education on self-management and quality of life, controlling for demographic and clinical covariates. Statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board (IRB) of UMI (0428) prior to data collection.

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3. RESULT

A total of 200 hypertensive patients were enrolled, with 100 assigned to the intervention group and 100 to the control group. The mean age of participants was 54.2 years (SD = 9.1), with no significant difference between groups. The majority of participants were female (58.5%) and had completed secondary education (62%). Baseline characteristics, including duration of hypertension, comorbidities, and medication use, were comparable across groups ($p > 0.05$) (Table 1).

Table 1. Demographic and Clinical Characteristics of Participants (N = 200)

Variable	Intervention (n = 100)	Control (n = 100)	p-value
Age, mean (SD)	54.6 (9.3)	53.8 (8.9)	0.52
Female sex, n (%)	59 (59.0)	58 (58.0)	0.88
Education, n (%)			
Primary	18 (18.0)	20 (20.0)	0.77
Secondary	62 (62.0)	62 (62.0)	
Tertiary	20 (20.0)	18 (18.0)	
Duration of hypertension (years), mean (SD)	6.8 (3.5)	6.5 (3.2)	0.61
Comorbid diabetes, n (%)	22 (22.0)	24 (24.0)	0.74
Antihypertensive medication use, n (%)	100 (100.0)	100 (100.0)	–

Note: Independent t-tests were used for continuous variables and chi-square tests for categorical variables.

Descriptive statistics indicated higher mean scores in the intervention group for both self-management and quality of life at post-intervention (Table 2).

Table 2. Baseline and Post-Intervention Comparison of Outcome Variables

Outcome	Group	Baseline Mean (SD)	Post-Intervention Mean (SD)	Mean Change (Δ)	p-value
HSMBQ (self-management)	Intervention	70.1 (8.9)	78.4 (8.6)	+8.3	<0.001
	Control	69.8 (9.0)	70.2 (9.1)	+0.4	0.21
WHOQOL-BREF	Intervention	74.9 (10.5)	82.6 (10.2)	+7.7	<0.001
	Control	75.2 (10.8)	75.1 (11.0)	-0.1	0.88

Note: Within-group changes were analyzed using paired t-tests. Between-group differences in change scores were analyzed using independent t-tests.

Within-group analysis showed that the intervention group experienced significant improvements in both self-management and quality of life from baseline to post-intervention ($p < 0.001$), whereas no significant changes were observed in the control group. Between-group comparisons of change scores confirmed that improvements were significantly greater in the intervention group for both outcomes ($p < 0.001$).

Correlation analyses revealed that higher levels of education, shorter duration of hypertension, and participation in the intervention were positively associated with self-management and quality of life scores (Table 3).

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Table 3. Bivariate Correlations Between Independent Variables and Outcomes

Variable	Self-Management (r, p)	Quality of Life (r, p)
Age	-0.12, 0.08	-0.10, 0.12
Sex (female)	0.05, 0.41	0.07, 0.29
Education level	0.23, <0.01	0.21, <0.01
Duration of hypertension	-0.18, 0.01	-0.15, 0.03
Intervention group	0.42, <0.001	0.39, <0.001

Multiple regression analyses were performed to examine the independent effect of wearable-integrated education on outcomes while controlling for demographic and clinical variables. After adjustment, the intervention remained a significant predictor of both self-management and quality of life.

Table 4. Multivariate Regression Analysis Predicting Self-Management and Quality of Life

Predictor	β (Self-Management)	p-value	β (Quality of Life)	p-value
Intervention (vs. control)	0.39	<0.001	0.36	<0.001
Age	-0.08	0.19	-0.07	0.22
Sex (female)	0.04	0.48	0.05	0.42
Education level	0.18	0.01	0.16	0.02
Duration of hypertension	-0.14	0.03	-0.12	0.04
Comorbid diabetes	-0.06	0.31	-0.08	0.25

Note: Standardized beta (β) coefficients are reported. Adjusted $R^2 = 0.29$ for self-management and 0.26 for quality of life.

4. DISCUSSION

This study demonstrated that wearable-integrated education was associated with significant improvements in self-management behaviors and quality of life among patients with hypertension. These findings are consistent with previous evidence suggesting that the integration of wearable devices into chronic disease care may enhance patient adherence, blood pressure control, and overall well-being. For instance, Wang et al. (2025) reported that wearable devices supported better hypertension management in elderly patients, improving both compliance and quality of life. Similarly, Yuting et al. (2023) found that a mobile health intervention integrating wearable monitoring was associated with increased hypertension compliance, self-efficacy, and quality of life over a 12-week period.

Our findings extend this growing body of evidence by suggesting that combining continuous monitoring with structured education may provide broader benefits beyond clinical outcomes. Previous reviews indicate that digital health interventions for hypertension yield variable effects on blood pressure reduction, particularly across health-disparate populations (Katz et al., 2024). In the present study, improvements were observed in both behavioral and psychosocial outcomes, including self-management practices and quality of life, which may reflect enhanced patient engagement with health behaviors facilitated by wearable feedback and educational support. However, because this study did not directly measure intervention engagement, app usage intensity, or adherence to wearable-based feedback, the underlying mechanisms should be

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interpreted as plausible but not confirmed. This is consistent with systematic reviews indicating that the effectiveness of digital interventions often depends on user engagement and the quality of behavioral support provided (Li et al., 2020).

Our study confirmed that higher educational attainment was significantly associated with better self-management and quality of life outcomes. This resonates with the findings by Konlan & Shin (2023), who underscored health literacy as a critical determinant of effective hypertension management, patients with higher education generally demonstrate stronger comprehension of health information and greater confidence in using technology-enhanced interventions. In contrast, those with lower literacy levels may face challenges in understanding complex health information or operating digital tools, thus risking inequitable benefits across populations. This underscores the necessity of tailoring wearable-based educational interventions to different literacy levels. Enhancements, such as simplified language, visual aids, audio guidance, culturally adapted content, and involvement of caregivers or community health workers could help bridge literacy gaps and promote equity in health outcomes.

The 2023 randomized clinical trial by Zhang, Tan, and Wang (2023) found that a wearable monitoring device paired with a smartphone application significantly improved hypertension compliance, self-efficacy, and life quality in a low-resource rural setting in China.

The findings are also consistent with randomized and non-randomized trials demonstrating that wearable monitoring combined with mobile applications can improve hypertension-related outcomes, including self-efficacy, medication adherence, and quality of life (Zhang et al., 2023). Similarly, Wang et al. (2025) reported that wearable-based chronic disease management platforms improved adherence, blood pressure control, and quality of life among older adults with hypertension. Systematic reviews further support the potential of mHealth interventions to improve blood pressure control and health behaviors, although effects across behavioral domains remain heterogeneous and methodologically variable (Wu et al., 2025).

Clinically, these findings suggest that integrating wearable technologies with patient education may enhance patient engagement by providing continuous feedback that supports adherence to medication, diet, and lifestyle recommendations. This approach may also offer scalability advantages, particularly in resource-limited settings where frequent in-person follow-up is challenging. However, further research is needed to clarify the mechanisms through which such interventions exert their effects, particularly in relation to user engagement and long-term behavioral sustainability. The observed improvements in quality of life further support the value of holistic hypertension management approaches that extend beyond blood pressure control alone.

Study Limitations

This study has several limitations. The sample was drawn from a single clinical setting, which may limit generalizability to other populations or regions. In addition, follow-up duration was relatively short, precluding assessment of long-term sustainability of intervention effects. The reliance on participants with adequate digital literacy also introduces potential selection bias, as those less comfortable with technology were excluded. Furthermore, some unmeasured confounders, such as socioeconomic status and social support, could have influenced the outcomes.

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An additional limitation is that this study did not directly measure participant engagement with the wearable device or educational content (e.g., frequency of app use, response to feedback, or adherence to digital recommendations). Therefore, the mechanisms underlying the observed effects remain inferential rather than empirically verified.

5. CONCLUSION

In conclusion, wearable-integrated education was associated with significant improvements in self-management and quality of life among patients with hypertension. These findings support the integration of wearable devices into routine hypertension care as a promising strategy to empower patients and improve outcomes.

However, given the quasi-experimental design and single-setting recruitment, causal inference and generalizability of the findings are limited. Therefore, further randomized, multicenter studies with longer follow-up periods are required before widespread implementation can be confidently recommended. Future research should also evaluate long-term efficacy, cost-effectiveness, and strategies to overcome digital literacy barriers to maximize impact across broader populations.

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8. AUTHOR CONTRIBUTIONS

Conceptualization: SS, AA
Methodology: SS, AA, WOSA
Data collection: S, BS, WORS
Data analysis and interpretation: S, AA
Writing—original draft preparation: S
Writing—review and editing: AA, WOSA, BS, WORS
Supervision: AA
All authors have read and approved the final version of the manuscript.

9. CONFLICT OF INTEREST DISCLOSURE

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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10. DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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