Lifestyle and environmental stress as determinants of hypertension development in rural Indonesia: a multinomial logistic regression analysis

Gaya Hidup dan Stres Lingkungan sebagai Determinan Perkembangan Hipertensi di Pedesaan Indonesia: Analisis Regresi Logistik Multinomial

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ABSTRACT

Background: Global evidence indicates that lifestyle behaviors and environmental stress contribute to blood pressure regulation; however, studies examining their combined effects on hypertension severity, particularly in rural Indonesian populations, remain limited.

Objective: This study addresses this gap by applying multinomial logistic regression to predict hypertension stages and examine interactions between lifestyle and environmental stress.

Methods: A cross-sectional study was conducted among 373 adults with hypertension aged ≥45 years in three rural villages in Kuningan Regency, Indonesia, selected through purposive sampling. Lifestyle behaviors and environmental stress were assessed using validated questionnaires with acceptable internal consistency (Cronbach's α> 0.70). Blood pressure was classified into Stage 1, Stage 2, and Stage 3 hypertension. Multinomial logistic regression analyses adjusted for age, sex, body mass index, and hypertension duration were performed to estimate main and interaction effects.

Results: The model demonstrated strong predictive validity (χ^2= 174.10; p< 0.001). A healthy lifestyle was significantly associated with higher odds of Stage 1 (OR= 30.04) and Stage 2 hypertension (OR= 11.45) compared with Stage 3. Mild to moderate environmental stress also showed a protective association with hypertension severity (p< 0.01). A significant lifestyle–stress interaction (p< 0.05) indicated that a healthy lifestyle attenuated the adverse effects of severe stress, maintaining a high predicted probability of milder hypertension (0.67).

Conclusion: These findings provide empirical evidence from rural Indonesia that lifestyle behaviors and environmental stress function as independent and interactive predictors of hypertension severity, supporting adaptive and health promotion frameworks and community-based interventions aligned with Sustainable Development Goal 3.

Keywords: Environmental stress, hypertension, lifestyle

ABSTRAK

Latar Belakang: Bukti global menunjukkan bahwa gaya hidup dan stres lingkungan berperan dalam regulasi tekanan darah, namun kajian yang menelaah efek gabungan keduanya terhadap keparahan hipertensi, khususnya pada masyarakat pedesaan di Indonesia, masih terbatas.

Tujuan: Studi ini mengisi celah tersebut dengan menggunakan regresi logistik multinomial untuk memprediksi stadium hipertensi serta menganalisis interaksi antara gaya hidup dan stres lingkungan.

Metode: Penelitian ini menggunakan desain cross-sectional terhadap 373 penderita hipertensi berusia ≥45 tahun di tiga desa di Kabupaten Kuningan, yang dipilih melalui purposive sampling. Gaya hidup dan stres lingkungan diukur menggunakan kuesioner tervalidasi (Cronbach α > 0,70), sementara tekanan darah diklasifikasikan ke dalam Stadium 1, Stadium 2, dan Stadium 3. Analisis regresi logistik multinomial yang disesuaikan dengan usia, jenis kelamin, indeks massa tubuh, dan durasi hipertensi digunakan untuk menilai efek utama dan interaksi antarvariabel.

Hasil: Model menunjukkan validitas prediktif yang kuat (χ^2 = 174,10; p < 0,001). Gaya hidup sehat secara signifikan meningkatkan kemungkinan berada pada hipertensi Stadium 1 (OR= 30,04) dan Stadium 2 (OR= 11,45) dibandingkan dengan Stadium 3. Stres ringan hingga sedang juga berperan sebagai faktor protektif (p < 0,01). Interaksi gaya hidup dan stres signifikan (p < 0,05), menunjukkan bahwa gaya hidup sehat dapat meredam dampak stres berat dan mempertahankan probabilitas hipertensi ringan yang tinggi (0,67).

Simpulan: Studi ini memberikan bukti empiris baru dalam konteks pedesaan Indonesia bahwa gaya hidup dan stres lingkungan merupakan prediktor independen sekaligus interaktif terhadap keparahan hipertensi, serta memperkuat relevansi Model Adaptasi Roy dan Model Promosi Kesehatan Pender dalam mendukung pencapaian SDGs 3 melalui intervensi berbasis komunitas.

Kata kunci: Gaya hidup, hipertensi, stres lingkungan

INTRODUCTION

Hypertension remains one of the most serious global health problems. More than 1.28 billion adults worldwide live with high blood pressure, and the majority of them live in low- and middle-income countries [1]. This situation demonstrates that this preventable disease remains a real threat, especially in rural areas where access to health services and healthy lifestyle education is limited. In many communities, hypertension often goes undiagnosed until it reaches a severe stage, leading to cardiovascular complications that can reduce quality of life and productivity [2]. A similar situation occurs in Indonesia. Data from the Basic Health Research Riskesdas (2018) shows that the prevalence of hypertension increased from 25.8% in 2013 to 34.1% in 2018, with higher rates in rural areas [3]. In Kuningan Regency, the prevalence reached 36.5%, and nearly half of the cases remain undiagnosed [4]. This phenomenon reflects not only a medical issue but also a social one, where limited access to healthcare, economic pressures, and the burden of agricultural work create a high-risk environment for stress and unhealthy lifestyles [5].

Previous research has shown that a combination of biological, behavioral, and environmental factors influences blood pressure. A high-salt diet, lack of physical activity, smoking, and lack of sleep have been shown to increase the risk of hypertension [6][7]. Furthermore, environmental stressors such as overcrowding, pollution, and socioeconomic pressures also play a significant role in exacerbating the condition [8][9]. However, the interaction between these two factors, how lifestyle and environmental stressors mutually influence the severity of hypertension, has not been thoroughly studied, particularly in the context of rural agrarian communities in Indonesia, which have distinct social and cultural characteristics. A more contextualized understanding is crucial.

Global intervention models often fail to be fully implemented in rural areas because they fail to consider local social dynamics and environmental pressures [10]. An approach is needed that can explain how individuals adapt to environmental stress

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through promotional behaviors such as healthy lifestyles and stress management. In this context, Roy's Adaptation Model views environmental stress as a stimulus that demands adaptive responses both physiologically and psychologically, while Pender's Health Promotion Model emphasizes the importance of perceived benefits, intrinsic motivation, and social support in shaping healthy behaviors [9],[11].

The integration of these two theories allows for a more comprehensive understanding of how humans adapt to environmental stressors to maintain a healthy balance. Based on this framework, this study focuses on analyzing the influence of lifestyle and environmental stress on the severity of hypertension in a rural, agrarian community in Kuningan Regency and examining whether a good lifestyle can moderate the negative impact of stress on blood pressure. This research is expected to not only provide new empirical evidence for the development of community nursing science but also serve as a basis for designing community-based interventions that integrate healthy lifestyle education with stress management in a local cultural context. Previous studies have shown that unhealthy lifestyle behaviors and psychosocial stress are associated with poor blood pressure control and increased cardiovascular risk, particularly in resource-limited and rural settings [12][13]. Community-based interventions integrating lifestyle modification and stress management have also been reported to improve hypertension outcomes and self-management behaviors [14]. Thus, the results of this study can contribute to efforts to achieve Sustainable Development Goal (SDG) 3, namely ensuring healthy lives and improving well-being for all people at all ages [15].

METHODS

Study Design

This study employed a cross-sectional quantitative analytic design to examine the relationships among environmental factors, lifestyle behaviors, and hypertension severity in a high-risk rural population. The study was conducted in October 2024 in Kuningan Regency, West Java, Indonesia.

Data Source and Sampling Procedure

Three villages were purposively selected based on the 2022 Health Office report indicating the highest prevalence of hypertension, representing highland agrarian communities with distinctive socio-cultural characteristics. The target population consisted of residents aged ≥45 years diagnosed with hypertension by a health professional, who had lived in the study area for at least one year and were willing to participate. Exclusion criteria included individuals with cognitive impairment, pregnancy, or acute/post-hospitalization status of less than two weeks. The minimum sample size was calculated using Lemeshow's formula ($\alpha = 0.05$; power = 80%), resulting in 348 participants. To account for potential missing data, a total of 373 respondents were recruited using purposive sampling, proportionally distributed across the selected villages.

Variables of the study

The independent variables included environmental factors (environmental stress) and lifestyle behaviors (diet, physical activity, smoking, alcohol consumption, and stress management). The dependent variable was hypertension severity, classified into stages according to standard guidelines. Potential confounding variables included age, sex, body mass index, duration of hypertension, and history of chronic diseases.

Data Collection

Data were collected through direct measurements and structured questionnaires administered by trained health workers. Blood pressure measurements and questionnaire data were obtained during the same visit under standardized conditions.

Measurement and Instruments

Blood pressure was measured using a calibrated digital sphygmomanometer. Measurements were taken twice in a sitting position after at least 5 minutes of rest, with a 2-minute interval between readings; the average value was used for analysis. Hypertension stages were classified based on the International Society of Hypertension 2020 guidelines.

Lifestyle data were collected using the Lifestyle Assessment Questionnaire adapted from WHO STEPS and IPAQ, while environmental stress was assessed using the Environmental Stress Scale covering physical, social, and economic dimensions. Both instruments demonstrated good validity (CVI > 0.80) and reliability (Cronbach's α: lifestyle = 0.82; environmental stress = 0.78).

Ethical Considerations

This study received ethical approval from the Health Research Ethics Committee of Bhakti Husada Indonesia University (No. 023/VII/UBHI/KEPK/2024). Written informed consent was obtained from all respondents prior to participation.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics were used to summarize respondent characteristics. Bivariate analysis was conducted using the chi-square test to examine associations between independent variables and hypertension stage. Multivariate analysis was performed using multinomial logistic regression, with hypertension stage as the dependent variable and Stage 3 as the reference category, adjusting for confounders. Model fit was evaluated using the Likelihood Ratio Test and Goodness-of-Fit tests (Pearson and Deviance), while multicollinearity was assessed using Variance Inflation Factor (VIF < 10). Statistical significance was set at $p < 0.05$, with odds ratios (ORs) and 95% confidence intervals (CIs) reported.

RESULTS

Table 1. Sociodemographic and Clinical Characteristics of Respondents (n = 373)

Variable	Category	n	%
Age (years)	45–59	197	53%
	60–74	164	44%
	≥75	12	3%
Gender	Male	158	42%
	Female	215	58%
Education	Elementary	36	10%
	Middle	92	25%
	High	166	44%
	College	79	21%
Body Mass Index	Less	5	1%
	Normal	105	28%
	More	175	47%
	Obesity	88	24%
Duration of Hypertension	< 1 year	39	11%
	2-5 years	117	31%
	>5 years	217	58%
Income	< Rp. 2,500,000	273	73%
	Rp. 2,500,000 -5,000,000	91	24%
	>Rp. 5,000,000	9	3%

A total of 373 respondents who met the inclusion criteria participated in this study. The average age of respondents was 59.8 ± 8.7 years, with the majority being female

(63.5%). Most respondents had a Body Mass Index (BMI) ≥25 kg/m² (54.1%) and had suffered from hypertension for >5 years (58%). Table 1 presents the respondents' characteristics, indicating that most participants had a long duration of hypertension and were predominantly characterized by at-risk socioeconomic conditions and nutritional status. Subsequently, the bivariate associations between lifestyle, environmental stress, and hypertension severity were examined using cross-tabulation, as shown in Table 2.

Table 2. Cross Table between Lifestyle, Environmental Stress, and Hypertension Stages (n = 373)

Variable		Stage 1 (n, %)	Stage 2 (n, %)	Stage 3 (n, %)	Total (n, %)	p-value
Lifestyle	Healthy	141 (64,1%)	73 (33,2%)	6 (2,7%)	220 (100%)	0,0001
	Unhealthy	40 (26,1%)	54 (35,3%)	59 (38,6%)	153 (100%)	
Environmental Stress	Mild	132 (50,4%)	98 (37,4%)	32 (12,2%)	262 (100%)	0.0001
	Moderate	41 (53,9%)	23 (30,3%)	12 (15,8%)	76 (100%)	
	Severe	8 (22,9%)	6 (17,1%)	21 (60,0%)	35 (100%)	

Based on Table 2, there was a significant relationship between lifestyle and stage of hypertension (p = 0.0001). Respondents with a healthy lifestyle were mostly at stage 1 hypertension (64.1%), and only 2.7% reached stage 3. In contrast, in the group with an unhealthy lifestyle, the proportion of patients with stage 3 hypertension was much higher (38.6%), while only 26.1% were at stage 1. The analysis showed a significant association between the level of environmental stress and the stage of hypertension (p = 0.0001). Most respondents with mild stress were at stage 1 (50.4%), and only 12.2% had stage 3 hypertension. In the moderate stress group, a similar distribution pattern was seen, although the proportion of stage 3 hypertension increased slightly (15.8%).

Table 3. Multinomial logistic regression results for predictors of the stage of hypertension (n = 373)

| Predictor	B	SE	Wald	df	p-value	Exp (B)	95% CI for Exp(B)
Outcome: Stage 1 vs 3 Intercept	-1,98	0,52	14,44	1	0,001	-	-
Lifestyle (Healthy vs. Unhealthy)	3,40	0,47	51,85	1	0,001	30,0	11,9 – 75,84
Environmental Stress (Mild vs. Severe)	1,95	0,55	12,58	1	0,001	7,03	2,39– 20,63
Environmental Stress (Moderate vs. Severe)	1,82	0,63	8,38	1	0,004	6,15	1,80 – 21,01
Outcome: Stage 2 vs 3 Intercept	-1,74	0,50	11,96	1	0,001	-	-
Lifestyle (Healthy vs. Unhealthy)	2,44	0,47	26,46	1	0,001	11,45	4,52 – 28,99
Environmental Stress (Mild vs. Severe)	2,09	0,54	15,05	1	0,001	8,07	2,81 – 23,19
Environmental Stress (Moderate vs. Severe)	1,66	0,62	7,12	1	0,008	5,25	1,55 – 17,75

Table 3 shows that respondents with a healthy lifestyle had 30 times greater odds of being at stage 1 hypertension compared to stage 3 (OR = 30.04; 95% CI: 11.90-75.84; p < 0.001), and 11.45 times greater odds of being at stage 2 compared to stage 3 (OR = 11.45; 95% CI: 4.52-28.99; p < 0.001). These findings suggest that a healthy lifestyle is a strong protective factor in preventing the progression of hypertension. Meanwhile, respondents who experienced mild environmental stress had 7-fold odds of being at stage 1 (OR = 7.03; 95% CI: 2.39-20.63; p < 0.001) and 8-fold odds of being at stage 2

(OR = 8.07; 95% CI: 2.81-23.19; p < 0.001) compared to those who experienced severe stress. Respondents with moderate stress also showed increased odds of being at stage 1 (OR = 6.15; 95% CI: 1.80-21.01; p = 0.004) and stage 2 (OR = 5.25; 95% CI: 1.55-17.75; p = 0.008).

Table 4. Predicted Probability of Hypertension Stages Based on Lifestyle and Environmental Stress (n = 373)

Lifestyle	Environmental Stress	Prob Stage 1	Prob Stage 2	Prob Stage 3
Healthy	Mild	0.61	0.36	0.03
Healthy	Moderate	0.76	0.22	0.02
Healthy	Severe	0.67	0.33	–
Unhealthy	Mild	0.33	0.39	0.28
Unhealthy	Moderate	0.20	0.43	0.37
Unhealthy	Severe	0.08	0.11	0.81

Based on Table 4, multinomial logistic regression shows that lifestyle and stress levels significantly influence hypertension stages. Respondents with a healthy lifestyle had a higher probability of remaining in stage 1 hypertension across all stress levels: 60.6% (mild stress), 76.1% (moderate), and 66.7% (severe), with very low probabilities for stage 3 (≤3%). This indicates that a healthy lifestyle acts as a strong protective factor, even under higher stress.In contrast, those with an unfavorable lifestyle showed a shift toward more severe stages. Under mild stress, probabilities were distributed across stage 1 (32.9%), stage 2 (39.2%), and stage 3 (27.8%). With increasing stress, the likelihood of stage 3 rose substantially to 36.7% (moderate stress) and 80.8% (severe stress), while probabilities for stages 1 and 2 declined. Overall, these findings highlight that a healthy lifestyle mitigates the impact of stress on hypertension severity, whereas an unfavorable lifestyle increases the risk of progressing to more severe stages.
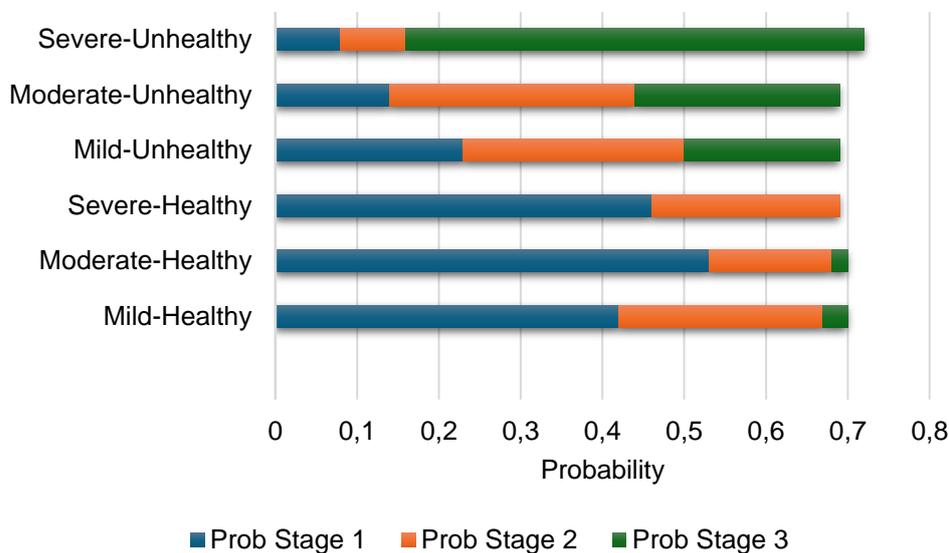
Figure 1. Predicted Probabilities of Hypertension Stages by Lifestyle Quality and Environmental Stress

Based on Table 5, multinomial logistic regression analysis showed that the model was significantly better than the intercept-only model (χ^2 = 174.104; df = 6; p < 0.001), as shown in Table 6. The model fit indices showed strong explanatory power: Cox & Snell R^2 = 0.373, Nagelkerke R^2 = 0.428, and McFadden R^2 = 0.228. The Nagelkerke R^2 value indicates that approximately 42.8% of the variation in hypertension severity in the rural

population can be explained by a combination of lifestyle factors and environmental stress. Meanwhile, the McFadden R² value falls within the "good fit" range for the health behavior model, strengthening the validity of the predictors in explaining categorical health outcomes.

The likelihood ratio test showed that lifestyle (χ^2 = 52.271; df = 2; p < 0.001) and environmental stress (χ^2 = 73.537; df = 4; p < 0.001) were significant predictors of the stage of hypertension, after controlling for age, gender, body mass index, duration of hypertension, and history of chronic diseases. This significant χ^2 value indicates that the two predictors contributed independently and not redundantly to the model. Overall, these results confirm that lifestyle and environmental stress play a central role in predicting hypertension severity in rural Indonesia, and reinforce the urgency of integrated community-based interventions to address behavioral and environmental determinants simultaneously.

Table 5. Model feasibility and Likelihood Ratio test of predictors of hypertension stage

Multinomial Statistics Test	Value	df	p-value
Model Fit Statistics			
-2 Log Likelihood (Intercept Only)	217.327		
-2 Log Likelihood (Final Model)	43.223		
Chi-square (Model Fit)	174.104	6	<0.001
Cox & Snell R²	0.373		
Nagelkerke R²	0.428		
McFadden R²	0.228		
Likelihood Ratio Test per Prediktor			
Lifestyle	52.271	2	<0.001
Environmental Stress	73.537	4	<0.001

DISCUSSION

This study confirms that a healthy lifestyle plays a crucial role in reducing the severity of hypertension in rural communities. Individuals who maintain a healthy lifestyle are significantly more likely to develop mild hypertension than those with severe hypertension, even when faced with high levels of environmental stress [17]. Conversely, severe stress has been shown to increase the risk of advanced hypertension significantly. These results demonstrate that lifestyle is not simply a daily habit but also a form of the body's adaptive mechanism against physical and psychosocial stress [18]. When viewed through Roy's Adaptation Model, environmental stress can be understood as a stimulus that demands an adaptive response from an individual's physiological and psychological systems [19]. When stress persists, the body activates the sympathetic nervous system and the HPA axis (hypothalamus-pituitary-adrenal axis), which triggers increased cortisol levels and blood pressure [20]. However, individuals with a healthy lifestyle appear to be able to maintain physiological stability through regular physical activity, a balanced diet, and good stress management. This means that healthy behaviors function as adaptive mechanisms that protect the body from the destructive effects of chronic stress.

Meanwhile, Pender's Health Promotion Model helps explain why healthy behaviors do not just emerge. Perceived benefits, social support, and intrinsic motivation influence promotive behavior. Individuals who recognize the benefits of a healthy lifestyle and are surrounded by a supportive social environment are more likely to maintain positive behaviors despite facing high levels of life stress [11]. In other words, a healthy lifestyle acts as a psychosocial buffer that strengthens resilience to stress, both mentally and physiologically. These findings also align with research in various developing countries [21]. Rahut et al. (2023) in South Asia found that a combination of stress, unhealthy diet, and physical inactivity contributed to the rise in hypertension cases in rural areas [22].

Studies in Ethiopia and Thailand also showed that physical activity and social support acted as a protective factor against high blood pressure [23][24]. However, the context of this study adds new value: although most respondents faced significant socioeconomic stress, those who adopted a healthy lifestyle still had a significantly lower risk of developing severe hypertension [25].

The social and spiritual conditions of rural Indonesian communities provide an interesting context for these findings. Family support, community togetherness, and spiritual practices such as dhikr (remembrance of God) or simple relaxation activities can strengthen individuals' adaptive capacity to cope with life's stresses. In this context, community nurses play a strategic role not only as providers of health education but also as facilitators of behavior change by strengthening motivation, cultural values, and social support. This is in line with research conducted by Arduzzi et al. (2025) [26]. From a theoretical perspective, this study extends the application of Roy's Adaptation Model and Pender's Health Promotion Model to agrarian communities in developing countries. The findings suggest that health-promoting behaviors act as moderating factors that enhance individuals' adaptive responses to environmental stress.

Practically, these results support the development of community-based nursing interventions that integrate lifestyle modification and stress management. However, the cross-sectional design limits the ability to establish causal relationships. The use of self-perception-based questionnaires may introduce bias; therefore, longitudinal studies incorporating objective biomarkers such as cortisol levels or heart rate variability are needed to strengthen causal evidence. Overall, this study highlights human adaptive capacity in maintaining balance between physiological and psychosocial responses under environmental stress. A healthy lifestyle reflects not only personal choice but also the ability to adapt and sustain health. A key strength of this study is the integration of Pender's Health Promotion Model and Roy's Adaptation Model, offering a comprehensive framework to understand how lifestyle and stress interact in shaping hypertension severity. Additionally, the use of multinomial logistic regression provides deeper insights than conventional binary analysis by capturing risk variations across multiple hypertension stages.

Despite these advantages, the study's cross-sectional design limits its ability to identify causal relationships among stress, lifestyle, and hypertension. Self-reported questionnaires are frequently used in community-based research; however, they may introduce social desirability or recall bias. To confirm stress reactions and adherence to lifestyle, future studies should use longitudinal designs and objective physiological measurements.

The findings have important implications for nursing practice, community health programs, and policy. Community-based interventions should emphasize lifestyle modification and stress management to prevent hypertension progression. Nurses, as frontline providers in rural areas, play a key role by integrating culturally relevant, family-oriented, and spiritually sensitive approaches into health promotion. Policymakers should support efforts to reduce environmental stressors and strengthen community resources that encourage healthy behaviors. Overall, these findings underscore the need for multisectoral collaboration to address hypertension in rural populations more comprehensively.

CONCLUSION

This study shows that healthy lifestyle behaviors and environmental stress significantly influence hypertension severity among rural populations in Kuningan, Indonesia. A healthy lifestyle increases the likelihood of remaining in stage 1 hypertension, even under high stress, indicating a strong protective effect. Using Roy's

Adaptation Model and Pender's Health Promotion Model, the findings suggest that adaptive physiological and psychosocial responses can be improved through health-promoting behaviors supported by motivation, positive perceptions, and social support. These results contribute to global evidence and provide context for developing community-based interventions in low-resource rural settings.

These findings suggest that future interventions should prioritize culturally appropriate lifestyle modification programs, including healthy diet, physical activity, and stress management tailored to rural communities. To improve adherence, community nurses and primary healthcare providers should strengthen health education, enhance social support, and incorporate culturally or spiritually relevant approaches. Policymakers are encouraged to expand community-based prevention efforts while addressing environmental stressors such as economic instability and limited healthcare access. Further research using longitudinal designs and objective biomarkers is recommended to better understand hypertension and improve intervention strategies in rural settings.

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