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Variability of blood pressure, pulse pressure, and mean arterial pressure in hypertensive individuals

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Abstract

Background: Hypertension is a major risk factor for cardiovascular disease and remains a public health issue, particularly in areas with limited access to healthcare services, such as the Indonesia–Timor Leste border region. Blood pressure variability, pulse pressure (PP), and mean arterial pressure (MAP) are important indicators for assessing the risks of long-term complications.
Purpose: To determine the profile and variability of blood pressure, PP, and MAP among hypertensive individuals, as well as the relationship between sociodemographic characteristics and these parameters.
Method: A quantitative descriptive design with a cross-sectional approach was employed. Data were collected from 124 respondents through blood pressure measurements taken at three different time points. Mean systolic and diastolic blood pressure (SBP and DBP), PP, and MAP were analyzed, along with comparisons between measurement times and respondent characteristics.
Result: The mean systolic blood pressure (SBP) was 151.27 mmHg, and the mean diastolic blood pressure (DBP) was 89.86 mmHg, indicating that most participants fell into hypertension grade 1–2 categories. The mean PP was 61.43 mmHg and MAP was 110.32 mmHg, both exceeding normal thresholds, suggesting potential vascular complications. Significant fluctuations were found in SBP and PP between the second and third measurements ($p=0.014$ and $p=0.032$, respectively), while DBP and MAP remained relatively stable. No significant associations were found between sex, education level, or occupation with the blood pressure parameters.
Conclusion: Blood pressure was relatively high and tended to be stable between measurements, with significant variability in systolic and pulse pressures ($p<0.05$). Meanwhile, sociodemographic characteristics such as age, gender, education, and occupation did not show a significant association with blood pressure, PP, or MAP.
Suggestion: Hypertension control programs need to focus on an individualized approach with routine blood pressure monitoring using HBPM, stabilizing blood pressure variability, and improving patient education. Programs must also be tailored to sociocultural conditions and supported by simple digital technology for early detection in border communities.

Keywords: HBPM; Hypertension; Mean Arterial Pressure; Pulse Pressure; Variability of Blood Pressure.

INTRODUCTION

Hypertension has long been a leading cause of global morbidity and mortality due to cardiovascular complications such as stroke, coronary heart disease, and kidney failure (Berek, Irawati and Hamid, 2021). The World Health Organization states that more than 1.28 billion people worldwide live with hypertension, and only 42% of them receive adequate treatment (Katete, 2023). The results of

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the 2023 Indonesian Health Survey showed a national prevalence of hypertension of 30.8%, with more than half of sufferers unaware that they have this disease. This condition emphasizes the importance of early detection and intensive monitoring of blood pressure, not only through regular blood pressure measurements but also by examining hemodynamic parameters such as pulse pressure (PP) and mean arterial pressure (MAP) (Ministry of Health of the Republic of Indonesia, 2023).

Pulse pressure and mean arterial pressure have an important role in evaluating cardiovascular risk in hypertensive patients (Taitoh, Berek and Rohi, 2025). High PP indicates arterial stiffness and is often associated with an increased risk of ischemic heart disease and stroke. Meanwhile, MAP is an important indicator of vital organ perfusion, particularly the brain and kidneys. The variability of these two parameters, which can be influenced by many factors including age, gender, and the body's response to antihypertensive treatment, has more profound prognostic value than relying solely on systolic and diastolic blood pressure (Cao, Cheng, Wei, Ding, Lu, Gao, & Huang, 2025).

East Nusa Tenggara a province with geographical challenges and limited access to healthcare, exhibits a high burden of hypertension. According to the 2018 basic health research the prevalence of hypertension in East Nusa Tenggara was 22.7%. Belu Regency, a border district in East Nusa Tenggara, showed an even higher rate, at 25.9%, making this region a highly vulnerable zone for hypertension complications. Haliwen community health center, as a primary healthcare facility in Belu Regency, handles a significant number of hypertension cases each year. Geographical, socioeconomic, limited health literacy, and adherence to therapy are key challenges in managing hypertension in this area (Ministry of Health of the Republic of Indonesia, 2018).

Previous research has revealed that lifestyles that include excessive salt consumption, smoking habits, and low physical activity are the dominant factors that cause uncontrolled blood pressure in patients (Baso, Berek, & Riwoerohi, 2019). In addition, other research on non-pharmacological interventions such as slow deep breathing, they demonstrated a significant reduction in blood pressure in hypertensive patients in Atambua. However, there has been little research explicitly examining pulse pressure variability and mean arterial pressure in this region. This indicates an important research gap that needs to be filled to strengthen local data-driven approaches to hypertension management (Berek, Nurachmah, & Gayatri, 2015).

PP and MAP variability are important indicators for identifying more comprehensive clinical conditions related to cardiovascular risk that may not be apparent through regular blood pressure measurements alone. Furthermore, the results of this study can contribute to the development of more accurate blood pressure monitoring protocols that are responsive to local conditions. By tailoring interventions based on hemodynamic parameters such as PP and MAP, healthcare providers can more accurately target therapy, monitor treatment success, and implement secondary prevention measures against complications.

RESEARCH METHOD

A quantitative design with a descriptive correlational approach was employed to analyze blood pressure variability, pulse pressure (PP), and mean arterial pressure (MAP) in hypertensive patients. This study will also use a longitudinal design to track changes in blood pressure variability over time, allowing for analysis of blood pressure fluctuations over time.

The population in this study were hypertensive patients who received treatment at the Haliwen Community Health Center. The total population of hypertensive patients at the Haliwen Community Health Center in one month was 182 patients. Using the Slovin formula, a sample of 124 hypertensive patients was obtained. The inclusion criteria for this study were patients with hypertension based on WHO criteria, aged 16 years and above, and patients who gave consent to participate in the study. The exclusion criteria were patients with hypertensive emergencies and secondary hypertension, patients who were unwilling to participate in the study, or did not give consent.

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Data collection was conducted through repeated blood pressure measurements in the Haliwen Community Health Center work area. Data collected included blood pressure measurements and blood pressure variability monitoring. Blood pressure was measured using an automatic digital blood pressure monitor. Measurements were taken three times, with a 15-minute interval between measurements to minimize the effects of hypertension or arrhythmias caused by stress. Blood pressure variability monitoring was performed three times to analyze patient blood pressure fluctuations. PP and MAP variability were calculated from the results of each measurement.

The instruments used in this study were a validated digital tensiometer, an observation form to record blood pressure data, PP and MAP variability, and a demographic data collection questionnaire to obtain information on age, gender, smoking status, medical history, and patient medication.

The collected data were analyzed using SPSS software. The analysis steps were as follows: Descriptive analysis to describe patient demographic data and calculate the mean, standard deviation, and frequency for the variables blood pressure, PP, and MAP. Correlation analysis to analyze the relationship between PP and MAP variability with patient sociodemographics using Pearson and Spearman correlation tests and ANOVA. T-test to compare the differences in blood pressure variability, PP, and MAP at each measurement.

This research complies with applicable ethical guidelines. Research permission was obtained from the Indonesian National Police, Belu Regency, under letter number: BKBP - 070/65/III/2025.

RESEARCH RESULTS

Table 1. Characteristics of the Respondents (N= 124)

Variable	Results	p-value			
		SBP	DBP	PP	MAP
Age (n/%)					
(Mean±SD)(Range)(Year)	(51.91±14.938)(16-81)				
16-35	24/19.4				
36-55	44/35.4				
56-81	56/45.2				
Gender (n/%)		0.843	0.845	0.983	0.866
Male	62/50.0				
Female	62/50.0				
Education (n/%)		0.348	0.500	0.777	0.261
Uneducated	35/28.2				
Elementary School	30/24.2				
Junior High School	15/12.1				
Senior High School	25/20.2				
College/University	19/15.3				
Occupation (n/%)		0.213	0.389	0.206	0.407
Student	8/6.4				
Civil Servant/Police	11/8.9				
Private/Self-Employed	13/10.5				
Farmer	29/23.4				
Housewife	48/38.7				
Retired	15/12.1				

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Table 1 shows that the average age is 51.91 years (SD 14.938). Gender is evenly divided between males and females (50%). There were no significant differences between men and women in any blood pressure parameters, including BP, DBP, PP, and MAP (P>0.05). Educational attainment varies, with the largest proportion being those with uneducated (28.2%), respondents' education level, ranging from uneducated to university, showed variation in mean blood pressure, but it was not statistically significant (P>0.05). In terms of occupation, the majority of respondents were housewives (38.7%), followed by farmers (23.4%), and retirees (12.1%), with the remainder being private employees/self-employed, civil servants/police officers, and students. Mean blood pressure across occupations (students, civil servants, private sector workers, farmers, housewives, and retirees) also showed no significant differences (P>0.05).

Table 2. Average Blood Pressure (BPs, BPd, PP, and MAP) for Each Measurement Period (N=124)

Variable	Mean±SD	Min – Max	95% CI	SE	p-value
SBP1	151.29±11.84	130-193	149.19-153.40	1.06	
SBP2	152.37±12.78	130-200	150.10-154.64	1.15	0.014*
SBP3	150.15±12.41	130-198	147.94-152.35	1.11	
Mean SBP	151.27±10.38	133-193	149.42-153.11		
DBP1	89.76±10.96	40-119	87.81-91.71	0.98	
DBP2	89.56±10.47	50-122	87.69-91.42	0.94	0.511
DBP3	90.29±12.16	50-126	88.13-92.13	1.09	
Mean DBP	89.86±7.75	93-119	88.48-91.24		
PP1	61.53±14.70	25-110	58.92-64.15	1.32	
PP2	62.81±16.77	30-120	59.83-65.80	1.50	0.032*
PP3	59.85±17.67	30-120	56.71-63.00	1.58	
Mean PP	61.43±12.48	40-97	59.21-63.65		
MAP1	110.29±8.88	77-138	108.71-111.87	0.79	
MAP2	110.48±8.07	87-144	109.05-111.92	0.72	0.815
MAP3	110.29±8.97	87-150	108.69-111.89	0.80	
Mean MAP	110.32±6.34	96-144	109.19-111.45		

*Significant on alpha < 0.05

Table 2 presents blood pressure measurements taken at three different time points. The average systolic blood pressure (SBP) was 151.27 mmHg (SD = 10.38), with values ranging from 133 to 193 mmHg. SBP remained relatively consistent across the three measurements, as reflected in similar mean values and narrow 95% confidence intervals. However, a significant difference was observed between the second and third SBP measurements (p = 0.014). The mean diastolic blood pressure (DBP) was 89.86 mmHg (SD = 7.75). Despite noticeable variation in the minimum and maximum readings, the mean and 95% CI were largely steady. No significant differences were detected across the three DBP measurements (p > 0.05). Pulse pressure (PP), calculated as the difference between SBP and DBP, averaged 61.43 mmHg (SD = 12.48), exceeding the normal range of 30–50 mmHg. A significant change was found between PP2 and PP3 (p = 0.032). The mean arterial pressure (MAP) averaged 110.32 mmHg (SD = 6.34), also surpassing normal physiological limits. MAP values were consistent across measurement times, indicating a stable blood pressure pattern among respondents. No significant differences were found in MAP across the three measurements (p > 0.05).

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DISCUSSION

The average age of respondents in this study was 51.91 years (SD=14.938), indicating that the majority were in the middle to elderly age group. Advanced age is closely associated with an increased risk of hypertension, as the aging process causes arterial stiffness and decreased endothelial function. Previous research has shown that the prevalence of hypertension increases significantly in individuals over 50 years of age, due to changes in the structure and function of blood vessels (Febriyanti, Yusri, & Fridalni, 2021). With age, blood pressure tends to increase physiologically due to natural changes in the cardiovascular system. One of the main causes is decreased elasticity of blood vessels, especially large arteries such as the aorta (Humphrey, 2021). The aging process causes blood vessel walls to become stiffer, requiring the heart to pump at higher pressures to circulate blood throughout the body. This contributes to increased systolic blood pressure, which is the main component of hypertension in the elderly population. Furthermore, the sensitivity of baroreceptors—the body's sensors that regulate blood pressure—also decreases with age (Laurent & Boutouyrie, 2020). As a result, the body's ability to adjust blood pressure to changes in body position or physiological stress is reduced. Aging also increases the risk of atherosclerosis, the buildup of fatty plaque on blood vessel walls, which narrows the arterial lumen and increases resistance to blood flow. This phenomenon has been supported by various studies. The 2017 guidelines from the American College of Cardiology and the American Heart Association confirmed that systolic blood pressure increases progressively with age and is the primary indicator of hypertension in the elderly also found that diastolic pressure tends to decrease with age, while systolic pressure increases, resulting in a wider pulse pressure. A World Health Organization (WHO) report supports this finding by stating that the prevalence of hypertension increases significantly in the population over 60 years of age (Kremer, Braisch, Rothenbacher, Denkinger, & Dallmeier, 2022; Chuang, Liu, Cheng, Chung, Lai, Chuang, & Hsu, 2024).

Biological and hormonal differences cause variations in the risk of hypertension between men and women, where men tend to experience hypertension earlier and women after menopause. Previous studies have found that men have higher blood pressure than women before age 60, but women have higher blood pressure after menopause due to declining estrogen. This gender balance allows for gender-based intervention approaches, such as education about postmenopausal risks for women and healthy lifestyles from a young age for men (Samargandy, Matthews, Brooks, Barinas-Mitchell, Magnani, Thurston, & El Khoudary, 2022; Humphrey, 2021).

Low education levels are associated with low health literacy, which results in delayed early detection, treatment, and adherence to chronic disease management. Previous research in BMC Cardiovascular Disorder showed that individuals with low education have a higher risk of hypertension and are less likely to adhere to treatment due to limited understanding of health information. Health communication strategies need to be tailored to respondents' literacy levels through visual media, direct communication, and family involvement to facilitate understanding and adoption of healthy behaviors (Guo, Jin, Mao, Zhu, Zhou, Ge, & Yu, 2023).

Occupation reflects lifestyle, physical activity levels, stress, and exposure to environmental risks, all of which influence cardiovascular health. Previous research in Circulation Research stated that informal workers, such as farmers and housewives, tend to have less access to health facilities and are at higher risk of delayed hypertension diagnosis. Health interventions should be community-based and mobile, reaching groups with limited access, such as farmers and housewives, and encouraging family participation in home health management, for example, through a family-based HBPM program (Samargandy et al, 2022).

The results of this study showed significant fluctuations in systolic blood pressure (SBP) and pulse pressure (PP) between the second and third measurements, with p values of 0.014 and 0.032, respectively. Meanwhile, diastolic blood pressure (DBP) and mean arterial pressure (MAP) remained relatively stable. These findings indicate short-term blood pressure variability, especially in the systolic and PP components, which are known to be

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independent markers of cardiovascular risk, as explained in previous studies that these fluctuations may reflect baroreflex dysfunction and increased arterial stiffness, two factors that contribute to the poor prognosis of hypertensive patients (Kario, 2021).

Support for these findings is also provided by a previous study, which reported that nocturnal systolic blood pressure variability is associated with increased cardiovascular events, independent of mean blood pressure and degree of arterial stiffness (Picard, Panagiotidou, Tammen, Wolf-Pütz, Steffen, Gerhardy, & Klein, 2022). Short-term blood pressure variability is associated with vascular structural changes, target organ damage, and the risk of stroke and cardiovascular mortality. Physiologically, reduced baroreflex sensitivity due to arterial stiffness contributes to increased PP and BPV, creating a pathophysiological cycle that worsens hemodynamic stability.

However, there is debate regarding the direction of the causal relationship between BPV and arterial stiffness, Studies suggest that the two may influence each other. Therefore, repeated and continuous blood pressure monitoring, such as through ambulatory blood pressure monitoring (ABPM) or home monitoring, is strongly recommended to detect variability not seen in a single measurement. The clinical implications of these findings support a therapeutic approach that targets not only mean blood pressure reduction but also stabilization of blood pressure (BP) and intraocular pressure (IPP), through a combination of pharmacological strategies, lifestyle modifications, and digital technology to enhance the baroreflex and reduce arterial stiffness (de la Sierra, 2023; Jhee, Oh, Seo, Lee, Chung, Park, & Yoo, 2023).

The results of the difference test showed significant fluctuations in systolic blood pressure (SBP) and pulse pressure (PP) between the second and third measurements ($p = 0.014$ and $p = 0.032$), while diastolic pressure (DBP) and Mean Arterial Pressure (MAP) did not show significant changes. This variability confirms that blood pressure is not always constant, especially in the systolic and PP components that are sensitive to time. Short-term blood pressure variability (short-term BPV), according to previous studies, is an independent predictor of cardiovascular events such as stroke and myocardial infarction, through mechanisms such as "BP spikes" and impaired hemodynamic stability (Parati, Bilo, Kollias, Pengo, Ochoa, Castiglioni, & Zhang, 2023).

Physiologically, fluctuations in blood pressure and heart rate are associated with vascular reactivity, arterial stiffness, and baroreflex dysregulation. Previous studies have highlighted a bidirectional relationship between BP and arterial stiffness, which has implications for the progression of hypertensive disease, renal impairment, and cognitive impairment. However, the effectiveness of conventional antihypertensive therapy in controlling BP remains questionable (Laurent et al., 2020; Kim, 2023; Cao et al. 2025). Previous studies have also shown that monotherapy is more effective in reducing mean BP than stabilizing variability, suggesting the need for a more integrative intervention approach (Lamptey, Sun, Layek, & Singh, 2023).

From a clinical perspective, continuous blood pressure monitoring through methods such as ambulatory blood pressure monitoring (ABPM) or home monitoring is highly recommended to identify fluctuating patterns not captured by a single measurement. Hypertension management interventions should target not only mean BP reduction but also BPV stabilization through a combination of pharmacotherapy, lifestyle modification, and the use of digital technology. The significant variations in SBP and PP found in this study warrant clinical attention, as they may be early indicators of vascular dysfunction and long-term cardiovascular risk.

The analysis results showed no significant relationship between gender and all blood pressure parameters ($p > 0.05$). Men and women had nearly the same mean blood pressure, indicating that in this population, gender is not a major determinant of blood pressure variation. This is in line with several studies showing that gender differences in blood pressure become more pronounced with age, especially after menopause in women, but are not always seen in the general middle-adult population.

Based on education level, the analysis results showed no significant relationship between education level and blood pressure variability, PP, and MAP ($p > 0.05$). Although the mean blood

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pressure in the elementary school and junior high school tended to be slightly higher, this difference was not statistically significant. This indicates that in the context of this study, formal education level is not a dominant factor influencing blood pressure profiles, although several previous studies have suggested that low education levels may be associated with a lack of understanding regarding hypertension prevention and control.

There was also no significant relationship between occupation and variability in blood pressure, PP, and MAP ($p>0.05$). The highest mean SBP was found in the retiree group (157.20 mmHg), followed by housewives (151.73 mmHg), while the lowest value was found in the private sector group (148.69 mmHg). Although there were differences in the mean values, these fluctuations were not statistically significant and may be influenced by individual variations such as age, physical activity, and work stress.

In general, these results indicate that sociodemographic factors such as gender, education, and occupation did not show a significant association with the variability of blood pressure, pulse pressure, and mean arterial pressure in this study population. However, it is important to note that the tendency for higher averages in certain groups (e.g., retirees and junior high school background) may be an early signal of susceptibility to hypertension that needs further longitudinal follow-up.

Physiologically, blood pressure is influenced by many factors, including genetics, diet, lifestyle, age, and hormonal status. Therefore, it is not surprising that sociodemographic factors such as education or occupation do not always show a strong direct relationship in certain contexts. These results also reinforce the importance of regularly measuring individual blood pressure, rather than relying solely on demographic predictors.

Previous research has shown results that both support and contradict these findings. One study stated that blood pressure tends to be higher in low-educated populations due to limited access to health services (Mi, Han, Cao, Cheng, Pan, Guo, & Guan, 2024). Conversely, another study found that the effect of education on blood pressure was insignificant when lifestyle factors such as diet and physical activity were strictly controlled (Karmakar, Bhattacharyya, Biswas, Dasgupta, Bandyopadhyay, & Paul ,2023).

The results of this study indicate that hypertension control strategies should not be focused solely on patient demographics. Individualized, risk-based, and standardized intervention programs, such as home-based blood pressure monitoring, are more targeted and have the potential to significantly impact patient blood pressure control, regardless of educational background, occupation, or gender.

CONCLUSION

Blood pressure was relatively high and tended to be stable between measurements, with significant variability in systolic and pulse pressures ($p<0.05$). Meanwhile, sociodemographic characteristics such as age, gender, education, and occupation did not show a significant association with blood pressure, PP, or MAP.

SUGGESTIONS

Hypertension control programs need to focus on an individualized approach with routine blood pressure monitoring using HBPM, stabilizing blood pressure variability, and improving patient education. Programs must also be tailored to sociocultural conditions and supported by simple digital technology for early detection in border communities.

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