JGPS, November 2025, Volume 9 Nomor 2
ISSN 2599-0152 eISSN 2599-2465
http://jos.unsoed.ac.id/index.php/jgps

BMI, WAIST CIRCUMFERENCE, VITAMIN D INTAKE , AND CALCIUM INTAKE IN RELATION TO HYPERTENSION AMONG MENOPAUSAL WOMEN IN BANDUNG

BMI, Waist Circumference, Vitamin D Intake , and Calcium Intake in Relation to Hypertension Among Menopausal Women in Bandung

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ABSTRACT

Menopausal women are more vulnerable to hypertension due to hormonal changes, particularly the decline in estrogen. This vulnerability is further increased by lifestyle-related factors such as excess body weight, abdominal fat, and inadequate nutrient intake.Menopause and hypertension are prevalent health issues in Bandung, yet studies examining how body mass index (BMI), waist circumference, vitamin D intake, and calcium intake affect the risk of hypertension remain limited. This study was conducted to address that gap. To examine the relationship between BMI, waist circumference, vitamin D intake, and calcium intake with the occurrence of hypertension among menopausal women in Bandung. A cross-sectional study was carried out from January to March 2025 among 70 menopausal women aged 45–60 years in Sukajadi District, Bandung. Data were obtained through interviews, anthropometric measurements, blood pressure assessments, and dietary evaluations using a semi-quantitative food frequency questionnaire (SQ-FFQ). Associations were analyzed using the Chi-square test. Hypertension was significantly associated with BMI (OR=11.27; p<0.05), waist circumference (OR=7.85; p<0.05), and low vitamin D intake (OR=9.67; p<0.05). Calcium intake showed no significant association. Excess weight and low vitamin D intake are major contributors to hypertension among menopausal women. Preventive strategies focusing on weight control and sufficient nutrient intake are essential.

Keywords: *bmi; calcium; hypertension, menopause; vitamin d*

ABSTRAK

Wanita menopause lebih rentan mengalami hipertensi akibat perubahan hormonal, khususnya penurunan kadar estrogen. Kerentanan ini semakin meningkat karena faktor gaya hidup seperti kelebihan berat badan, penumpukan lemak abdominal, serta asupan zat gizi yang tidak memadai. *Menopause* dan hipertensi merupakan masalah kesehatan yang banyak dijumpai di Bandung, namun penelitian mengenai pengaruh indeks massa tubuh (IMT), lingkar pinggang, asupan vitamin D, dan asupan kalsium terhadap risiko hipertensi masih terbatas. Penelitian ini dilakukan untuk menjawab kesenjangan tersebut. Mengetahui hubungan antara IMT, lingkar pinggang, asupan vitamin D, dan asupan kalsium dengan kejadian hipertensi pada wanita menopause di Bandung. Penelitian potong lintang dilakukan pada Januari–Maret 2025 dengan melibatkan 70 wanita menopause berusia 45–60 tahun di Kecamatan Sukajadi,

DOI 10.20884/1.jgipas.2025.9.2.17797

Bandung. Data diperoleh melalui wawancara, pengukuran antropometri, pemeriksaan tekanan darah, serta penilaian asupan makanan menggunakan semi-quantitative food frequency questionnaire (SQ-FFQ). Hubungan antarvariabel dianalisis dengan uji Chi-square. Hipertensi berhubungan signifikan dengan IMT (OR=11,27; p<0,05), lingkar pinggang (OR=7,85; p<0,05), serta asupan vitamin D rendah (OR=9,67; p<0,05). Asupan kalsium tidak menunjukkan hubungan bermakna. Kelebihan berat badan dan rendahnya asupan vitamin D menjadi faktor utama hipertensi pada wanita menopause. Strategi pencegahan yang menekankan pengendalian berat badan dan kecukupan gizi sangat diperlukan.

Kata Kunci : hipertensi; imt; kalsium; *menopause*; vitamin d

INTRODUCTION

Menopause is a natural physiological transition in women, typically occurring between the ages of 48 and 55. It is marked by the permanent cessation of menstruation for at least twelve consecutive months, primarily due to the decline in ovarian hormone production (Peacock et al., 2023). The resulting hormonal changes particularly the reduction in estrogen levels can trigger a wide range of physical and psychological symptoms, while also elevating the risk for non-communicable diseases such as hypertension. One of the key mechanisms is the failure of the ovaries to respond to gonadotropins, which significantly contributes to reproductive dysfunction during the menopausal transition (Vender, 2019). In addition to vasomotor symptoms like hot flashes, estrogen deficiency has been linked to increased cardiovascular risk, notably hypertension, which can impair quality of life and daily functioning (Tasić, 2022).

Postmenopausal hypertension frequently presents as isolated systolic hypertension, attributed to vascular stiffness, smooth muscle proliferation, and collagen deposition in arterial walls. The protective vascular effects of estrogen are lost during menopause, which, when compounded by a sedentary lifestyle, insufficient vitamin D and calcium intake, and high levels of psychosocial stress, can further aggravate hypertensive risk (Cormick et al., 2022). Menopausal symptoms such as fatigue, insomnia, and reduced physical activity have a direct negative impact on health and overall well-being (Lopes et al., 2018; Marwaha, 2022).

Globally, an estimated 50.8% of women across 32 countries have been diagnosed with hypertension, with only 11.7% achieving adequate blood pressure

DOI 10.20884/1.jgipas.2025.9.2.17797

control (WHO, 2021). The incidence of vitamin D and calcium deficiency is notably high among postmenopausal women due to physiological changes associated with estrogen decline. Reduced estrogen levels impair intestinal calcium absorption and decrease renal 1α-hydroxylase activity, reducing the conversion of vitamin D into its active form (Mei & Li, 2023; Khabaz et al., 2023). These disruptions in vitamin D and calcium metabolism contribute to hypertension through endothelial dysfunction, impaired vascular smooth muscle regulation, and activation of the renin–angiotensin–aldosterone system (RAAS), which elevates vascular resistance and blood pressure (Faraji & Ebrahimzadeh, 2019; Cormick et al., 2022).

Similarly, BMI and waist circumference tend to increase in postmenopausal women due to hormonal changes that promote visceral fat accumulation, reduce basal metabolic rate, and lead to unfavorable changes in body composition (Nguyen et al., 2022; Hafid, 2018). Visceral fat accumulation triggers inflammation, insulin resistance, and sympathetic activation, all of which are strongly linked to hypertension (Zhao et al., 2021; Kim & Lee, 2018). Given these trends in the study population where overweight and central obesity are prevalent evaluating vitamin D and calcium intake alongside BMI and waist circumference is essential to understand their combined influence on hypertension risk among postmenopausal women.

Reaching 658,201 nationwide, with West Java among the provinces with the highest prevalence (39.6%) (Kemenkes, 2018). In Bandung alone, there were 137,754 hypertension cases, accounting for 19.78% of all public health center visits (Dinkes Bandung, 2021). The Sukajadi District chosen as the study site has a particularly high concentration of menopausal women, comprising 57.8% of the total menopausal population across 49 integrated health posts. Bandung's population includes approximately 1,226,915 residents, 49.7% of whom are women, and West Java has 4,714,600 women aged 45–60 (BPS, 2023).

Although prior studies have identified various risk factors for hypertension such as excessive sodium intake, physical inactivity, and stress, few have explored the combined impact of vitamin D and calcium intake alongside BMI and waist circumference

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among menopausal women in Bandung. Vitamin D deficiency has been shown to contribute to hypertension through activation of the renin angiotensin aldosterone system (RAAS), reduced nitric oxide production, endothelial dysfunction, and increased arterial stiffness, all of which elevate blood pressure. When low vitamin D and calcium intake occur together with excess body weight and abdominal fat, the risk of hypertension becomes even greater due to the synergistic effects of impaired vascular regulation, chronic inflammation, and heightened sympathetic activity.

The selection of BMI and waist circumference as variables in this study was based on their strong association with cardiometabolic risk and their tendency to increase after menopause. In the study area, a notable trend shows that many menopausal women experience rising BMI and abdominal fat accumulation, with a high prevalence of overweight and central obesity. These patterns indicate that BMI and waist circumference are relevant predictors of hypertension risk in this population.

METHOD

Design, place and time

This study employed a quantitative cross-sectional design to investigate the relationship between BMI, waist circumference, vitamin D intake, calcium intake, and hypertension. The research was conducted in the Sukajadi District, Bandung, spanning from January to March 2025.

Number and method of taking research subjects/ tools and material

The study on the relationship between BMI, waist circumference, vitamin D intake, calcium intake, and hypertension involved 70 menopausal women, aged 45 to 60 years, residing in the Sukajadi District, Bandung. Participants were selected using a purposive non-probability sampling technique, with the sample size determined by the Lemeshow formula. Data were collected using structured interviews and questionnaires. The research tools and materials included anthropometric tools for measuring weight, height, and waist circumference; a sphygmomanometer for blood pressure readings; and a semi-quantitative food frequency questionnaire (SQ-FFQ) to assess vitamin D and calcium intake, with analysis conducted using the

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Indonesian Food Composition Table (DKBM).

Types and methods of data collection/research steps

In this study, primary data was collected through structured interviews and questionnaires. The research steps included gathering demographic information, performing anthropometric measurements for BMI and waist circumference, taking blood pressure readings, and assessing dietary intake of vitamin D and calcium. Dietary intake of vitamin D and calcium was assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). The development of the food list for the SQ-FFQ followed several steps. First, the researcher identified commonly consumed foods that are sources of vitamin D and calcium among menopausal women in Bandung. This identification was based on preliminary survey findings, local dietary habits, and references from the Indonesian Food Composition Table (DKBM). Second, the selected food items were grouped into relevant categories such as dairy products, fish, eggs, fortified foods, vegetables, and commonly consumed processed foods.

For each food item, standard portion sizes (household measures) and consumption frequency options (per day, per week, or per month) were determined. The portion sizes and frequency categories were adapted from national dietary guidelines and typical consumption patterns in the study population. Total vitamin D and calcium intake was then calculated using the Indonesian Food Composition Table (DKBM), based on the reported frequency, portion size, and nutrient content of each food item.

Data analysis

Data analysis for this study was performed using Microsoft Excel and SPSS version 25. The analysis included univariate analysis to describe the sample characteristics and bivariate analysis using the Chi-square test to examine the associations between categorical variables.

RESULT AND DISCUSSION

The characteristics of the respondents examined in this study include age, occupation, education, age at menopause, duration of menopause,

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husband's income, and wife's income. Table 1 below presents the distribution data based on the characteristics of the respondents studied in this research.

Table 1. Distribution based on Respondent Characteristics

Characteristics	Frequency (n)	Precentage (%)
Age		
45-50	7	10
51-55	26	37.1
56-60	37	52.9
Min – Max	45-60	
Occupation		
Private Sector	1	1.4
Enterpreneur	3	4.3
Teacher	5	7.1
Housewife	60	85.7
Civil Servant	1	1.4
Min – Max	1-60	
Education		
Elementry School	13	18.6
Junior High School	17	24.3
Senior High School	32	45.7
Diploma (D3)	2	2.9
Bachelor's Degree (S1)	6	8.6
Min – Max	2-60	
Menopause Age		
< 45 years	9	12.9
45-50 years	43	61.4
51-55 years	17	24.3
56-60 years	1	1.4
Min – Max	29-56	
Duration of Menopause		

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Characteristics	Frequency (n)	Precentage (%)
1-5 years	37	
6-10 years	18	
>10 years	15	
Min – Max	1-19	

Based on the results in Table 1, most respondents are aged between 56 and 60 years. The average age of the respondents is 55 years, with an age range from 45 to 60 years. The majority of respondents are housewives with a secondary education level, while respondents with higher education levels such as associate (D3) and bachelor's degrees (S1) are fewer than 10 individuals. Most respondents entered menopause between the ages of 45 and 50, with an average duration of menopause of 6.47 years.

Table 2 presents the distribution data of respondents based on BMI and waist circumference as examined in this study. Body Mass Index (BMI) categories in this study were classified according to the World Health Organization criteria (WHO, 2000). Waist circumference categories were determined based on the *World Health Organization Expert Consultation on Waist Circumference and Waist–Hip Ratio* guidelines (WHO, 2008).

Table 2. Distribution of Respondents Based on BMI and Waist Circumference

Categories	Frequency (n)	Precentage (%)
Body Mass Index (BMI)		
Obesity II (>27 kg/m^2)	33	47.1
Obesity I (25-27 kg/m^2)	22	31.4
Normal (18.5-25 kg/m^2)	13	18.6
Underweight (17-<18.5 kg/m^2)	2	2.9
Min – Max	2-33	
Waist Circumference		
Central Obesity (≥ 80cm)	55	78.6

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Categories	Frequency (n)	Precentage (%)
Normal (< 80 cm)	15	21.4
Min – Max	64-109	

Based on Table 2, the majority of respondents fall into the obesity category II, followed by obesity category I, while only a small portion have normal or underweight nutritional status. Most respondents also have waist circumferences that fall into the central obesity category. These findings indicate a high prevalence of excessive nutritional status and suggest a higher potential health risk due to fat accumulation in the abdominal area.

Body Mass Index (BMI)

The analysis showed indicate a relationship between BMI and the incidence of hypertension in postmenopausal women. Most respondents were classified as having obesity levels I and II. BMI was significantly associated with hypertension because obesity particularly the accumulation of visceral fat affects various physiological mechanisms that contribute to increased blood pressure. One of the main mechanisms is the activation of the sympathetic nervous system, in which excess fat tissue stimulates the release of catecholamines, causing vasoconstriction and increased heart rate.

Additionally, obesity activates the RAAS (Renin-Angiotensin-Aldosterone System), which leads to sodium and water retention, thereby increasing blood volume and vascular pressure. Excess fat also contributes to insulin resistance and chronic inflammation, which impair endothelial function and narrow blood vessels. This study shows that individuals with obesity have a significantly higher risk of hypertension compared to those with normal weight, and the prevalence of hypertension increases with higher BMI (Zhou et al., 2021). Therefore, obesity is not only a strong risk factor but also a modifiable one in the prevention and control of hypertension.

However, one study found no significant relationship between obesity and hypertension in postmenopausal women. This discrepancy is thought to be influenced by respondent characteristics such as healthier dietary patterns, higher levels of physical activity, and differences in the BMI

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classification criteria used in that particular study (Wang et al., 2022).

Waist Circumference

The analysis showed show a significant relationship between waist circumference and the incidence of hypertension in postmenopausal women. The majority of respondents in this study had a waist circumference of ≥80 cm, indicating a high prevalence of central obesity. This suggests that women with waist circumferences exceeding the normal threshold have a higher risk of hypertension compared to those with normal waist measurements.

Waist circumference reflects the accumulation of visceral fat, a type of fat that surrounds internal organs in the abdominal cavity. This fat is metabolically active and triggers conditions such as insulin resistance, activation of the sympathetic nervous system, and the RAAS (Renin-Angiotensin-Aldosterone System), all of which contribute to increased blood pressure (Nguyen et al., 2022; Zhao et al., 2021). Furthermore, visceral fat produces pro-inflammatory cytokines such as TNF-α and IL-6, which cause chronic inflammation and endothelial dysfunction (Gonzalez et al., 2020), thereby accelerating the development of hypertension.

A study by (Kim et al.,2018) showed that each 1 cm increase in waist circumference could raise the risk of hypertension by 2–3%. Meanwhile, (Wang et al.,2022) found that individuals with higher waist circumferences have a 2–3 times greater risk of developing hypertension. This condition is further exacerbated in postmenopausal women, who generally experience reduced physical activity, hormonal changes, and increased caloric intake that does not align with the decline in metabolic rate (Hafid, 2018). However, one study found no significant relationship between waist circumference and the incidence of hypertension. This difference is thought to be influenced by sample characteristics, such as higher levels of physical activity, lower stress, and the predominance of a Mediterranean diet in that region (Bonofiglio, 2022). Table 3. Show that distribution of respondents based on vitamin D and calcium intake as examined in this study.

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Table 3. Distribution of Respondents based on Vitamin D and Calcium Intake

Categories	Frequency (n)	Precentage (%)
Vitamin D Intake		
Low (<12ng/mL)	43	61,4
Adequate (≥ 12 ng/mL)	27	38,6
Mean ± SD	16-10,4	
Min – Max	2,53-43,1	
Calcium Intake		
Inadequate (≤ 924 mg/day)	34	48.6
Adequate (≥ 924mg/day)	36	51.4
Mean ± SD	970.5-251.3	
Min – Max	589.6-2006.5	

The categories for vitamin D and calcium intake were determined based on Natiomal Institutes of Health (NIH) recommends a daily vitamin D imtake (NIH,2022). A cutoff of ≥12 ng/mL was used to classify adequate vitamin D intake/status, while ≥924 mg/day was used as the recommended intake level for calcium in adult women. Based on Table 3, most respondents have low vitamin D levels (<12 ng/mL), and only a small proportion meet the adequate vitamin D intake threshold (≥12 ng/mL). In contrast, the majority of respondents achieve adequate calcium intake (≥924 mg/day), although a considerable number still fall below the recommended value.

Vitamin D Intake

The analysis shows a significant relationship between vitamin D intake and the incidence of hypertension among menopausal women. Most respondents had low vitamin D intake, suggesting that inadequate vitamin D levels may contribute to increased blood pressure. Vitamin D plays an important role in regulating blood pressure through several physiological mechanisms, such as suppression of the Renin Angiotensin Aldosterone System (RAAS), improvement of endothelial function, and reduction of systemic inflammation. (Mei, 2023; Khabaz et al., 2023). A lack of vitamin D can activate the RAAS, reduce NO bioavailability, and lead to endothelial dysfunction, all of which

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contribute to elevated blood pressure (Faraji, 2019; Mei, 2023). Therefore, adequate dietary intake of vitamin D is considered important in hypertension prevention strategies, particularly among menopausal women who are at higher risk of deficiency (Mei, 2023; Khabaz et al., 2023).

Calcium Intake

The analysis showed no significant relationship between calcium intake and the incidence of hypertension in postmenopausal women. Although most respondents had calcium intake below the recommended dietary allowance, this was not directly associated with elevated blood pressure. The physiological effects of calcium on blood pressure depend on several factors, including its bioavailability, vitamin D status, interactions with other minerals (such as sodium and magnesium), and hormonal conditions like estrogen levels in postmenopausal women (Yang & Hori, 2021; Li et al., 2024).

Vitamin D also plays an important role in blood pressure regulation through its involvement in calcium absorption and vascular function. Low vitamin D status has been associated with impaired calcium metabolism, increased activity of the renin–angiotensin system, inflammation, and reduced vasodilation, all of which may contribute to elevated blood pressure (Chen et al., 2023; Li et al., 2024). Despite these mechanisms, the present study did not find a significant association between vitamin D intake and hypertension. This may be due to variability in dietary sources, differences in sunlight exposure among respondents, or the fact that dietary intake alone may not accurately reflect overall vitamin D status.

Physiologically, calcium supports vascular smooth muscle contraction and relaxation, while vitamin D helps regulate endothelial function and calcium homeostasis. Deficiencies in either nutrient may contribute to vascular stiffness or impaired vasodilation. However, dietary intake alone often does not exert a strong protective effect unless combined with other dietary and lifestyle factors. Evidence suggests that the benefits of calcium and vitamin D on blood pressure are more apparent when supported by a diet low in sodium and high in potassium, along with adequate sun exposure and overall nutritional adequacy (Pont et al., 2024; Chen et al., 2023).

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Therefore, while calcium and vitamin D remain important for maintaining vascular health, their direct effects on blood pressure appear inconsistent without considering broader dietary patterns, mineral interactions, and individual physiological conditions. The detailed distribution of respondents' calcium and vitamin D intake is presented in the table below to support these findings. Table 4 presents the data on the relationship between BMI and waist circumference with the incidence of hypertension.

Table 4. Relationship between BMI and Waist Circumference and the Incidence of Hypertension

Category	Blood Pressure Category										OR	P Value
	Hypertension Stage 2		Hypertension Stage 1		Pre hypertension		Normal		Total			
	n	%	n	%	n	%	n	%	n	%		
BMI												
Obesity 2	12	17.1	14	20	5	7.1	1	1.4	32	45.7		
Obesity 1	2	2.9	13	18.6	6	8.6	0	0	21	30,0	11,27	0.000
Normal	0	0	3	4.3	8	11.4	4	5.7	15	21.4		
Underweight	0	0	0	0	1	1.4	1	1.7	2	2.9		
Waist Circumference												
Central Obesity	13	18.6	26	37.1	11	15.7	1	1.4	51	72.9	17,86	0.000
Normal	1	1.4	4	5.7	9	12.9	5	7.1	19	27.1		

BMI categories were classified according to the World Health Organization (WHO, 2000). Waist circumference categories were based on the WHO Expert Consultation on Waist Circumference and Waist–Hip Ratio (WHO, 2008).

Based on Table 4, there is a significant relationship between the incidence of hypertension and both BMI and waist circumference ($p < 0.05$). Respondents with an obese nutritional status have an 11.27 times higher risk of developing hypertension compared to those with normal BMI. Similarly, respondents with an obese waist circumference have a 7.85 times greater risk of experiencing hypertension compared to those with normal waist circumference. These findings highlight that obesity whether measured by overall adiposity (BMI) or central adiposity (waist circumference) is a

DOI 10.20884/1.jgipas.2025.9.2.17797

major and independent risk factor for hypertension.

Although no specific subtitle was previously provided for BMI and waist circumference, these indicators warrant focused discussion because both measures reflect different physiological mechanisms associated with hypertension. BMI represents total body fat accumulation, which increases cardiac output, activates the sympathetic nervous system, and promotes renal sodium retention mechanisms known to elevate blood pressure. Meanwhile, central obesity measured by waist circumference is strongly associated with visceral fat, which increases inflammatory cytokines, insulin resistance, and activation of the renin angiotensin aldosterone system (RAAS), all of which contribute to elevated blood pressure.

These findings are consistent with high-quality evidence showing that central adiposity is a stronger predictor of hypertension compared to BMI. A large prospective cohort study demonstrated that waist circumference was significantly associated with incident hypertension even after adjusting for BMI (Wang et al., 2022). Another analysis from the China Health and Nutrition Survey found that individuals with normal BMI but high waist circumference had substantially higher odds of hypertension, underscoring the importance of measuring central obesity (Chen et al., 2023). Furthermore, a systematic review reported that both BMI and waist circumference are independent predictors of hypertension, but waist circumference shows a more consistent dose-response relationship (Jayedi et al., 2022). Given this evidence, including a dedicated discussion of BMI and waist circumference strengthens the interpretation of findings and aligns the manuscript with current global guidelines that emphasize central obesity as a critical cardiometabolic risk factor.

Table 5 presents the data on the relationship between vitamin D and calcium intake with the incidence of hypertension.

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Table 5. The Relationship Between Vitamin D and Calcium Intake and the Incidence of Hypertension

Intake	Blood Pressure Category										OR	P Value
	Hypertension Stage 2		Hypertension Stage 1		Pre hypertension		Normal		Total			
	n	%	n	%	n	%	n	%	n	%		
Vitamin D Intake												
Low	13	18.6	26	37.1	19	27.1	3	4.3	61	87.1	9,67	0.031
Adequate	1	1.4	4	5.7	1	1.4	3	4.3	9	12.9		
Calcium												
Inadequate	10	14.3	23	32.9	11	15.7	5	7.1	49	70	0,44	0.348
Adequate	4	5.7	7	10	9	12.9	1	1.4	21	30		

Based on Table 5, there is a significant relationship between vitamin D intake and the incidence of hypertension ($p < 0.05$), where respondents with low vitamin D intake were 9.67 times more likely to develop hypertension compared to those with adequate intake. This aligns with recent evidence showing that individuals with higher predicted serum 25(OH)D levels have a lower risk of developing hypertension, as demonstrated in a large Mediterranean cohort (Xu *et al*., 2024). However some meta-epidemiological analyses indicate that when publication bias is adjusted for, the association between vitamin D and hypertension may weaken (Bae, 2022).

Anthropometric indicator such as BMI and waist circumference in this study also show strong relationships with blood pressure categories. This is consistent with robust epidemiological evidence indicating that central obesity particularly waist circumference is a strong independent predictor of hypertension risk (Wang *et al* ., 2022). Similarly, recent cohort data from the China Health and Nutrition Survey demonstrate that even normal-weight individuals with central obesity have significantly higher odds of hypertension (Chen *et al*., 2023). Overall, these findings support the interpretation that low vitamin D intake and central adiposity may act synergistically in increasing hypertension risk among menopausal women. Future studies should incorporate biochemical assessments of serum 25(OH)D, control for central obesity, and use longitudinal designs

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to clarify the causal pathways leading to hypertension.

CONCLUSION

This study found significant associations between modifiable factors body mass index (BMI), waist circumference, and vitamin D intake and the incidence of hypertension among menopausal women in Bandung. Respondents with obesity (both in terms of BMI and central obesity) and low vitamin D intake had a significantly higher risk of hypertension. While calcium intake did not show a statistically significant relationship with hypertension, trends indicated that inadequate calcium may still contribute to increased risk when combined with other dietary and physiological factors.

These findings highlight the importance of managing body weight, reducing abdominal fat, and ensuring adequate vitamin D intake in reducing hypertension risk during the menopausal period. Given the prevalence of obesity and low vitamin D levels in the studied population, public health interventions should prioritize dietary education, physical activity promotion, and nutritional strategies tailored to menopausal women. Future research should explore these relationships further using longitudinal or interventional designs, and include objective biomarkers to strengthen causal inferences. Overall, this study emphasizes the critical role of lifestyle and nutritional modifications in the prevention and management of hypertension in menopausal populations.

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