



The Effect of Residential Altitude and Body Mass Index on the Incidence of Hypertension

Edgina Khairunnisa¹, Yusuf Alam Romadhon²

¹Faculty of Medicine, Muhammadiyah University of Surakarta

²Department of Family Medicine, Faculty of Medicine, Muhammadiyah University of Surakarta

*Corresponding Author: Edgina Khairunnisa

E-mail: yar245@ums.ac.id



Article Info

Article history:

Received 30 September 2024

Received in revised form 28 October 2024

Accepted 13 November 2024

Keywords:

Highlands

Lowlands

Body Mass Index

Hypertension

Abstract

Non-communicable diseases (NCDs) are diseases that are not transmitted from one individual to another, but these diseases develop slowly and have long episodes. One of the most common non-communicable diseases (NCDs) is hypertension. The number of adults aged 30-79 years experiencing hypertension is around 1.28 billion worldwide. The prevalence of hypertension in Indonesia is estimated at 34.1%, showing an increase from 2013 of 25.85%. The prevalence of hypertension in Central Java is the largest case of all non-communicable diseases, which is 76.5%. The prevalence of hypertension in Kendal Regency always increases every year. In 2019 it was around 9.74%, in 2020 it was around 18.21%, and in 2021 it was around 32.32%. Objective: This study aims to analyze the effect of residential altitude characteristics and body mass index (BMI) on the incidence of hypertension. This study uses observational analytics with a cross-sectional research design. The sampling technique uses purposive sampling technique. Statistical analysis with univariate analysis using Chi-square and multivariate analysis using logistic regression. Based on the results of the regression model equation show that the probability value (predicted) is 0.408. This shows that the sample in this study who have a residence with a residential altitude of 650 meters above sea level ++ and have a BMI with the Overweight/obese category will be predicted to experience hypertension with a predicted value of 0.408. It was found that the characteristics of being left behind are more significant in influencing the incidence of hypertension compared to body mass index, although both are considered risk factors.

Introduction

Non-communicable diseases (NCDs) are diseases that are not transmitted from one individual to another, but these diseases develop slowly and have long episodes (Risksedas, 2018). One of the non-communicable diseases (NCDs) that often occurs is hypertension. The number of adults aged 30-79 years experiencing hypertension is around 1.28 billion worldwide (WHO, 2023)

The prevalence of hypertension in Indonesia is estimated at 34.1%, showing an increase from 2013 of 25.85%. (Risksedas, 2018). The prevalence of hypertension in Central Java is the largest case of all non-communicable diseases, which is 76.5% (Dinas Kesehatan Provinsi Jawa Tengah, 2021). The prevalence rate of hypertension in Kendal Regency always increases every year. In 2019 it was around 9.74%, in 2020 it was around 18.21%, and in 2021 it was around 32.32% (Dinas Kesehatan Kabupaten Kendal, 2021).

The characteristics of a place of residence are also related to a person's physiological adaptation response to environmental conditions (Multazam et al., 2020). A study shows that people who live at high altitudes have a higher prevalence of hypertension compared to those who live in the lowlands, this is caused by several factors including the body's adaptation to a hypoxic environment (lack of oxygen), diet, lifestyle, and physical activity that can affect blood pressure (Zhang et al., 2022).

Accumulation of fat in the body occurs due to lack of physical activity and hormonal changes in the elderly, which can trigger excess weight and obesity, which is one of the factors causing high blood pressure and can be determined through body mass index (BMI) (Sofa, 2018). Based on research by Azzahra et al., there are correlation test results with a p value = 0.000, which means that there are significant results between body mass index and blood pressure (Nexiary & Dagradi, 2024). This is different from the research conducted in Dusun Maju Jaya, Kuamang Kuning 1 Health Center Working Area in 2023, the results of the study showed a p value = 0.433, which means that there is no significant relationship between body mass index and the incidence of hypertension (Nur et al., 2024). Based on the results of the description above, researchers are interested in conducting research on the effect of residential altitude and body mass index on the incidence of hypertension.

Methods

This study used an analytical observational method with a cross-sectional approach. This study was conducted in August-September 2024, with the research location at the Plantungan Health Center (highlands) and the Cepiring Health Center (lowlands), Kendal Regency. The population of this study were participants of the Integrated Development Post in May-July 2024 in Plantungan District and Cepiring District, Kendal Regency. The sample size was calculated using the lemshow formula and obtained 96 samples for each health center. Sampling used a purposive sampling technique. The inclusion criteria for this study were all participants of the Integrated Development Post aged ≥ 40 years, from Plantungan District representing the highlands and Cepiring District representing the lowlands, and had complete health records including; address, height, weight, and blood pressure. The type of data used is secondary data. The variables studied were the height of the residence (highlands and lowlands) measured using Google Earth, body mass index (BMI) obtained from medical record data, and hypertension obtained from medical records. Statistical analysis with univariate analysis using Chi-square and multivariate analysis using logistic regression. This study has received permission from the Faculty of Medicine, Muhammadiyah University of Surakarta No. 4382 / C.4-III / FK / VIII / 2024 and research approval from the Head of the National Unity and Politics Agency of Kendal Regency No. 000.9 / 1691 / 2024.

Result and Discussion

This study aims to analyze the effect of residential altitude and body mass index on the incidence of hypertension. This study was conducted in Plantungan District and Cepiring District, Kendal Regency. The samples used came from medical records of the Integrated Development Post participants at the Plantungan Health Center and Cepiring Health Center in the period May-July 2024 using a *purposive sampling technique*. A total of 413 samples were obtained, secondary data taken in this study included name, age, gender, BMI, and address. The results of the study will be described in the data analysis section using the SPSS 25 program.

Descriptive analysis

Based on the research results, it is known that the characteristics of respondents based on age, gender, BMI and blood pressure can be seen in the following table:

Table 1. Respondent Characteristics

Variables	Frequency (N)	Percentage (%)
Age		
<40 years	312	75.54
>60 years	101	24.46
Gender		
Man	89	21.5
Woman	324	78.5
Body Mass Index		
<i>Under/ normoweight</i>	223	53.9
<i>Overweight/obese</i>	190	46.1
Blood pressure		
<i>Normotensive</i>	338	81.8
<i>Hypertension</i>	75	18.2
Total	413	100.0

Source: Secondary data (2024)

Table 1 shows that based on age characteristics, the majority of respondents in this study were aged <40 years with a total of 312 respondents (75.54%). Based on gender characteristics, it is known that the majority of respondents in this study were female with a total of 324 respondents (78.5%). Based on body mass index (BMI) characteristics, it is known that the majority of respondents in this study had a BMI in the *under/normoweight* category with a total of 223 respondents (53.9%). Based on blood pressure, it is known that the majority of respondents in this study had *normotensive* blood pressure with a total of 338 respondents (81.8%).

Bivariate Analysis

The bivariate test in this study aims to determine the effect of residential altitude and body mass index (BMI) on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. The bivariate test in this study was conducted using the *Chi Square test*. The results of the bivariate test in this study are as follows:

The Effect of Residential Altitude on the Incidence of Hypertension

Based on the results of the analysis test, it is known that the influence of residential altitude on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency is as follows:

Table 2. Effect of residential altitude on hypertension

Height of residence (masl)	Blood pressure		Bivariate Analysis	
	Normotensive (n= / Σ (%))	Hypertension (n= / Σ (%))	p	OR
<650 masl	215 (63 , 6)	123 (36 , 4)	0 ,000	3,294
650 masl ++	26 (34 , 7)	49 (65 , 3)		

Source : Secondary data (2024).

Based on table 2 it is known that based on the results of the analysis with use *Chi Square* test shows that the *p-value* obtained is 0.000 (0.000 <0.05) with an *odd ratio* (OR) value of 3.294. This shows that there is an effect of residential altitude on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. The large *odd ratio* (OR) value shows that people living in the lowlands (<650 masl) are at 3.294 times greater risk of experiencing hypertension compared to people living in the highlands with an altitude of 650 masl ++.

The effect of body mass index on the incidence of hypertension

Based on the results of the analysis test, it is known that the influence of body mass index on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency is as follows:

Table 3. Effect of body mass index on the incidence of hypertension

Body Mass Index	Blood pressure		Bivariate Analysis	
	Nomoterency (n= / Σ(%))	Hypertension (n= / Σ(%))	p	OR
Under/ normoweight	134 (60 , 1)	89 (39 , 9)	0 , 438	1 , 168
Overweight/obese	107 (56 , 3)	83 (43 , 7)		

Source : Secondary data (2024).

Table 4.3 shows that based on the results of the analysis with use *Chi Square* test shows that the *p-value* obtained is 0.438 ($0.000 < 0.05$) with an *odd ratio* (OR) value of 1.168. This shows that there is no effect of body mass index on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency.

Multivariate Analysis

The multivariate test in this study aims to determine the effect of residential altitude and body mass index (BMI) on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. Multivariate testing in this study was conducted using logistic regression tests. The results of the multivariate test in this study are as follows:

Table 4. The Effect of Residential Altitude and Body Mass Index (BMI) on the Incidence of Hypertension

Variables	B	P-value	Hosmer and Lemeshow Test	Nails R Square
Constant	-0.886	0,000	0.173	0.086
Residence	1,187	0.070		
IMT	0.390	0.183		

Source: Secondary data (202 4)

Based on the results of the multivariate analysis using the logistic regression test above, the regression model can be written as follows:

$$Y = -0.886 + 1.187(\text{Residence}) + 0.390(\text{BMI}) + e$$

From the regression model above, the results can be interpreted as follows:

$$\text{Probabilitas (Predicted)} = (\exp (-0,886 + (1,187 \times 1) + (0,390 \times 1)) / (1 + \exp (-0,886 + (1,187 \times 1) + (0,390 \times 1)))$$

$$\text{Probabilitas (Predicted)} = (\exp (0,691) / (1 + 0,691))$$

$$\text{Probabilitas (Predicted)} = (0,691 / 1,691)$$

$$\text{Probability (Predicted)} = 0.408$$

Based on the results of the regression model equation, it is known that the value of the probability (*predicted*) is of 0.408. This shows that if the sample in this study who has a residence with a residential altitude of 650 meters above sea level ++ and has a BMI with the Overweight/obese category, it will be predicted to experience hypertension with a prediction value of 0.408.

The Influence of Residential Altitude Characteristics on the Incidence of Hypertension

Based on the study, it is known that there is an influence of residential altitude characteristics on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. This is evidenced by the large *p-value* obtained of 0.000 ($0.000 < 0.05$) with an *odd ratio* (OR) value of 3.294. Residential altitude characteristics are closely related to the incidence of hypertension (Prihanto et al., 2024). A study in the Himalayan, Tibetan, and Andes mountains showed a higher prevalence of hypertension in residents living in highland areas compared to those living at lower altitudes. This is caused by several factors including the body's adaptation to a hypoxic environment (lack of oxygen), lifestyle, diet and physical activity so that it can affect blood pressure (Zhang et al., 2022)

The characteristics of a residence are also related to a person's physiological adaptation response to environmental conditions (Multazam et al., 2020). Physiological adaptation responses in residents in the highlands and lowlands are influenced by differences in atmospheric pressure (P_{atm}) and partial pressure of oxygen (PO_2) which can affect physiological processes in the body. People in the lowlands have higher PO_2 , while people in the highlands have low levels of O_2 in their bodies. Therefore, people who live in the highlands will experience hypoxia. Hypoxia is a condition where the body lacks oxygen (Ferdian et al., 2020). Continuous hypoxia can cause increased activation of the sympathetic nervous system which has an impact on increased cardiac output, heart rate, and peripheral vasoconstriction (Verma & K Pal, 2017). So that it can cause increased blood pressure and increased risk of hypertension (Salipadang et al., 2022). The results of this study are in line with the results of research conducted by Verratti et al., 2020 which found that there is an influence of the characteristics of residential altitude on the incidence of hypertension ($P < 0.05$).

The Effect of Body Mass Index on Hypertension Incidence

Based on the study, it is known that body mass index has an effect but is not significant on the incidence of hypertension. So it can be concluded that although body mass index is not a major risk factor, body mass index has an effect on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. Body mass index (BMI) is a method of measuring body proportions. BMI itself is one of the parameters to determine the ideal weight range, so that it can predict health risks that can occur due to being overweight or not ideal weight (Sabaruddin, 2020).

A study from *the China Health and Nutrition Survey* found that individuals with a higher BMI, especially those classified as obese, had a greater risk of developing hypertension (Ren et al., 2023). The mechanisms underlying obesity-related hypertension are complex, including overactivation of the sympathetic nervous system (SNS), stimulation of the renin-angiotensin-aldosterone system (RAAS) resulting in increased renal sodium reabsorption, and increased blood volume and blood pressure (Shariq & McKenzie, 2020). The results of this study are in line with the results of a study conducted by Yulanda & Diani, 2021 which found that there was no significant relationship between BMI and the incidence of hypertension at the Barimba Kapuas Hilir Health Center, Kapuas Regency in 2020. The results of another study conducted by Nur et al., 2024 which also found that there was no significant relationship between Body Mass Index (BMI) and the incidence of hypertension in Dusun Maju Jaya, the working area of the Kuamang Kuning I Health Center in 2023.

The Influence of Residential Altitude Characteristics and Body Mass Index on the Incidence of Hypertension

Based on the results of the regression model equation, it is known that the magnitude of the probability value (*predicted*) is 0.408. This shows that if the sample in this study who has a residence with a height of 650 meters above sea level ++ and has a BMI with the *Overweight/obese category*, it will be predicted to experience hypertension with a predicted

value of 0.408. People who live in lowlands have higher PO₂, while people who live in highlands have low levels of O₂ in their bodies. Therefore, people who live in highlands will experience hypoxia. Hypoxia is a condition where the body lacks oxygen (Ferdian et al., 2020). Continuous hypoxia can cause increased activation of the sympathetic nervous system which has an impact on increased cardiac output, heart rate, and peripheral vasoconstriction (Verma & K Pal, 2017). So that it can cause increased blood pressure and increased risk of hypertension (Salipadang et al., 2022).

The risk factors for hypertension also increase, along with increasing body weight or obesity. Obesity is a condition where there is excessive fat accumulation in adipose tissue so that it can interfere with health (Gunawan et al., 2019). Some complications of obesity-related diseases, such as type 2 diabetes mellitus, cardiovascular disease, and psychosocial (WHO, 2024). The underlying mechanisms of hypertension related to obesity are very complex including excessive activation of the sympathetic nervous system (SNS), stimulation of the renin-angiotensin-aldosterone system (RAAS) which increases sodium reabsorption in the kidneys, then increases blood volume and blood pressure (Shariq & McKenzie, 2020).

The results of this study also found that the majority of respondents in this study were aged <40 years. Age is one of the main factors that influences the incidence of hypertension (Tindangen et al., 2020). As a person ages, there are changes in the arteries in the body that become wider and stiffer, resulting in a reduced capacity and recoil of blood accommodated through the blood vessels (Nuraeni, 2019). This reduction causes systolic pressure to increase. In addition, increasing age due to the aging process also causes disruption of neurohormonal mechanisms such as the *renin-angiotensin-aldosterone system* and also causes increased peripheral plasma concentrations and also the presence of glomerulosclerosis due to aging and intestinal fibrosis resulting in increased vasoconstriction and vascular resistance, resulting in increased blood pressure (hypertension) (Nurhayati et al., 2023).

The results of this study also found that the majority of the study was female. The prevalence of hypertension in men is almost the same as in women, but after menopause, the risk of hypertension increases (Yunus et al., 2021). Before menopause, women are protected by the hormone estrogen which plays a role in increasing *High Density Lipoprotein (HDL) levels*. High HDL cholesterol levels are a protective factor in preventing atherosclerosis. After menopause, HDL cholesterol levels in women decrease. This affects the occurrence of atherosclerosis which has an impact on causing high blood pressure (Nurhayati et al., 2023). The results of this study are in line with the results of research conducted by Falah, 2019 there was a significant relationship between gender and the incidence of hypertension in Tamansari sub-district, Tasikmalaya city.

Conclusion

Based on the results of the study and discussion above, it is concluded that there is a significant relationship between the height of the residence and the incidence of hypertension in Kendal Regency with a *p-value* of 0.000 (<0.05), but the results of the body mass index (BMI) with the incidence of hypertension *p-value* obtained were 0.438 (0.000 <0.05) with an *odd ratio* (OR) value of 1.168. This shows that there is no significant effect of body mass index on the incidence of hypertension in Plantungan District and Cepiring District, Kendal Regency. And based on the results of the regression model equation, it is known that the magnitude of the probability value (*predicted*) is 0.408. This shows that if the sample in this study who has a residence with a height of 650 meters above sea level ++ and has a BMI in the *Overweight/obese category*, it will be predicted to experience hypertension with a predicted value of 0.408. Overall, it was found that the characteristics of the residence were more significant in influencing the incidence of hypertension compared to body mass index, although both were considered risk factors.

References

- Dinas Kesehatan Kabupaten Kendal. (2021). *Profil Kesehatan Kabupaten Kendal Tahun 2021*.
- Dinas Kesehatan Provinsi Jawa Tengah. (2021). *Profil Kesehatan Jawa Tengah Tahun 2021*.
- Falah, M. (2019). Hubungan jenis kelamin dengan angka kejadian hipertensi pada masyarakat di kelurahan tamansari kota tasikmalaya. *Jurnal Mitra Kencana Keperawatan Dan Kebidanan*, 3(1), 85–94. <https://doi.org/10.54440/jmk.v3i1.67>
- Ferdian, F., Limanan, D., Ferdinal, F., & Yulianti, E. (2020). Pengaruh hipoksia sistemik kronik terhadap aktivitas spesifik enzim katalase pada darah dan paru tikus Sprague dawley setelah diberi daun ara. *Tarumanagara Medical Journal*, 2(2), 259–266. <https://doi.org/10.24912/tmj.v3i1.9726>
- Gunawan, I., Ichwansyah, F., & Abdullah, A. (2019). Hubungan obesitas dengan kinerja petugas kesehatan di Puskesmas Kabupaten Bireuen. *Action: Aceh Nutrition Journal*, 4(1), 49–57. <https://doi.org/10.30867/action.v4i1.157>
- Multazam, A., Irawan, D. S., Amandhea, S. H., Hidayat, E. N., Zikrullah, R. A., & Abdullah, A. (2020). Hubungan high altitude terhadap kemampuan fungsional paru pada perokok di desa ngadas kecamatan poncokusumo kabupaten malang. *J Sport Science*, 4681, 144–152. <http://dx.doi.org/10.17977/um057v10i2p144-152>
- Nexiary, A. B. A., & Dagradi, E. M. (2024). Perbandingan Tekanan Darah pada Masyarakat Dataran Tinggi dan Dataran Rendah serta Korelasinya dengan Indeks Massa Tubuh dan Konsumsi Makanan Asin. *Jurnal Ilmiah Kesehatan Masyarakat: Media Komunikasi Komunitas Kesehatan Masyarakat*, 16(3).
- Nur, A., Syahputra, C., & Enopadria, C. (2024). Hubungan Indeks Massa Tubuh dengan Kejadian Hipertensi Pada Lansia di Dusun Maju Jaya Wilayah Kerja Puskesmas Kuamang Kuning I. *Jurnal Ilmu Kesehatan Mandira Cendikia*, 3(2), 114–120.
- Nuraeni, E. (2019). Hubungan usia dan jenis kelamin beresiko dengan kejadian hipertensi di Klinik X Kota Tangerang. *Jurnal Jkft*, 4(1), 1–6. <http://dx.doi.org/10.31000/jkft.v4i1.1996.g1234>
- Nurhayati, U. A., Ariyanto, A., & Syafriakhwan, F. (2023). Hubungan usia dan jenis kelamin terhadap kejadian hipertensi. *Prosiding Seminar Nasional Penelitian Dan Pengabdian Kepada Masyarakat LPPM Universitas Aisyiyah Yogyakarta*, 1, 363–369.
- Prihanto, E. S. D., Giringan, F., Fahira, R. J., & Kamal, R. M. (2024). Perbandingan Hipertensi pada Masyarakat Yang Tinggal di Pesisir Pulau Maitara dan Daerah Dataran Tinggi Gurabunga Tidore. *Syntax Idea*, 6(2), 783–793. <https://doi.org/10.46799/syntax-idea.v6i2.2930>
- Ren, H., Guo, Y., Wang, D., Kang, X., & Yuan, G. (2023). Association of normal-weight central obesity with hypertension: a cross-sectional study from the China health and nutrition survey. *BMC Cardiovascular Disorders*, 23(1), 120. <https://doi.org/10.1186/s12872-023-03126-w>
- Riskesdas. (2018). *Riskesdas 2018*.
- Sabaruddin, F. (2020). *Analysis of Body Mass Index on Vo2Max Men Basketball Team Rooster Gowa Regency*.
- Salipadang, F. P., Danes, V. R., & Moningka, M. E. W. (2022). Hubungan Perbedaan Ketinggian dengan Perubahan Tekanan Darah pada Pelaku Perjalanan dari Dataran Rendah ke Dataran Tinggi dan dari Dataran Tinggi ke Dataran Rendah. *EBiomedik*,

- 10(1). <https://doi.org/10.35790/ebm.v10i1.37820>
- Shariq, O. A., & McKenzie, T. J. (2020). Obesity-related hypertension: a review of pathophysiology, management, and the role of metabolic surgery. *Gland Surgery*, 9(1), 80. <https://doi.org/10.21037/g.s.2019.12.03>
- Sofa, I. M. (2018). Kejadian Obesitas, Obesitas Sentral, dan Kelebihan Lemak Viseral pada Lansia Wanita The Incidence of Obesity, Central Obesity, and Excessive Visceral Fat among Elderly Women. *Amerta Nutr*, 228. <https://doi.org/10.20473/amnt.v2i3.2018.228-236>
- Tindangen, B. F. N. E., Langi, F. F. L. G., & Kapantow, N. H. (2020). Faktor-Faktor Yang Berhubungan Dengan Kejadian Hipertensi Pada Guru Sekolah Dasar Di Kecamatan Tombariri Timur. *Kesmas*, 9(1).
- Verma, N., & K Pal, A. (2017). Effect of Altitude on Blood Pressure. *Hypertension Journal*, 3(4), 171–172. <https://doi.org/10.5005/jp-journals-10043-0090>
- Verratti, V., Ferrante, C., Soranna, D., Zambon, A., Bhandari, S., Orlando, G., Brunetti, L., & Parati, G. (2020). Effect of high-altitude trekking on blood pressure and on asymmetric dimethylarginine and isoprostane production: Results from a Mount Ararat expedition. *The Journal of Clinical Hypertension*, 22(8), 1494–1503. <https://doi.org/10.1111/jch.13961>
- WHO. (2023, March 16). *Hipertensi*. WHO. <https://www.who.int/news-room/fact-sheets/detail/hypertension>
- Yulanda, B., & Diani, Y. H. (2021). Hubungan Indeks Massa Tubuh dan Hipertensi di Puskesmas Barimba Kapuas Hilir Kabupaten Kapuas Tahun 2020= The Association between Body Mass Index and Hypertension at the Barimba Kapuas Hilir Health Center, Kapuas Regency in 2020. *Majalah Kedokteran UKI*, 37(2), 49–53. <https://doi.org/10.33541/mk.v37i2.4823>
- Yunus, M., Aditya, I. W. C., & Eksa, D. R. (2021). Hubungan usia dan jenis kelamin dengan kejadian hipertensi di puskesmas haji pemanggilan kecamatan anak tuha kab. Lampung Tengah. *Jurnal Ilmu Kedokteran Dan Kesehatan*, 8(3), 229–239. <https://doi.org/10.33024/jikk.v8i3.5193>
- Zhang, X., Zhang, Z., Ye, R., Meng, Q., & Chen, X. (2022). Prevalence of hypertension and its relationship with altitude in highland areas: a systematic review and meta-analysis. *Hypertension Research*, 45(8), 1225–1239. <https://doi.org/10.1038/s41440-022-00955-8>