**Poltekita: Jurnal Ilmu Kesehatan**
e-ISSN: 2527-7170 dan p-ISSN: 1907-459X
Volume 19 Issue 1, 2025, page 77-85
DOI: 10.33860/jik.v19i1.4039
Website:https://ojs.polkespalupress.id/index.php/JIK
Publisher: Poltekkes Kemenkes Palu

**Original Article**

# A Multivariate Prediction Model for Hypertension Incidence

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**ARTICLE INFO**

**Article History:**
**Received:** 2024-11-30
**Published:** 2025-04-01

**Keywords:**
Hypertension; BMI; age; family history of hypertension; prediction model.

**ABSTRACT**

Hypertension is a significant global non-communicable disease and a leading cause of premature death. This study aimed to develop a multivariate prediction model for hypertension incidence in the Banggai Community Health Center working area, Central Sulawesi, Indonesia. An analytical observational study with a case-control design was conducted involving 140 people, equally divided into case and control groups. Data were collected on age, family history of hypertension, obesity status, smoking status, coffee consumption habits, use of hormonal birth control, and place of residence. Univariate, bivariate, and multivariate analyses were performed. The final regression model included sex, age, family history of hypertension, body mass index (BMI), and smoking status, which together could predict hypertension incidence by 59.3%. Family history of hypertension was the most dominant variable, with those having a history being 25.6 times more likely to develop hypertension than those without a history ($p < 0.001$). Age ≥ 36 years, obesity, and smoking were also significant risk factors. The prediction model is useful for assessing individual hypertension risk and guiding early diagnosis and treatment. Family-based health education and screening for non-communicable diseases based on the prediction variables are recommended to reduce hypertension prevalence. Future research should consider prospective designs, involve more samples, and include additional variables such as diet, physical activity, and stress level to enhance the model's predictive accuracy.



## INTRODUCTION

Hypertension is a significant global non-communicable disease. In the past, people knew hypertension as "high blood pressure" because the disease indicated a high increase in blood pressure beyond normal limits. Hypertension is the leading cause of premature death globally.[1] According to WHO, around 1.28 billion adults between 30 and 79 years globally have hypertension, with most (two-thirds) residing in low- and middle-income countries.[1] The highest prevalence of hypertension is found in Africa at 27%, followed by the Eastern Mediterranean at 26%, Southeast Asia at 25%, Europe at 23%, the Western Pacific at 19%, and the Americas at 18%.[2]

The 2023 Indonesian Health Survey (SKI) shows that the prevalence of hypertension in 2023 is 8%. Central Sulawesi is included in the 10 provinces with the highest incidence of hypertension, with a prevalence of 8.3%, which is still above the national figure.[3] Specifically in the working area of the Banggai Community Health Center (one of the Community Health Centers in Central Sulawesi), an

increasing trend was obtained over 3 years (2018-2020) of 21.2% (profile of the Banggai Laut Health Service in 2018; 2019; 2020).

The worst impact of hypertension is the "silent killer" which means it can kill silently and can happen at any time because someone suffering from hypertension does not show symptoms.[4] It is estimated that 46% of adults with hypertension do not realize that they have the disease until the sufferer's condition becomes severe and causes complications with other diseases.[5] And only about 1 in 5 adults (20%) with hypertension can control it.[1]

Controlling hypertension or other non-communicable diseases can be done through early detection and management of risk factors. Many individuals with hypertension do not engage in regular health check-ups or risk factor management. WHO shows that less than half of adults (42%) with hypertension can be diagnosed and treated.[1] research conducted by Kurdi in 2022 shows that 60% of hypertension sufferers do not have regular health checks.[6] Therefore, knowledge about risk factors is essential for everyone to know.[7]

Hypertension is a non-communicable disease caused by multiple factors. Hypertension risk factors are categorized into two groups: those that can be controlled and those that cannot. Risk factors that can be controlled include food consumption, low physical activity, cigarette consumption, alcohol consumption habits, stress, estrogen use and being overweight or obese. Meanwhile, risk factors that cannot be controlled include age, gender, family history and genetics.[8] In general, hypertension does not show symptoms. Prevention can be achieved by predicting events based on various factors, which requires multivariate testing.

Determinants and their roles in the occurrence of a disease can differ in each population group. Likewise, in the Banggai Community Health Center Working Area. Therefore, this research is important to produce a prediction model for the incidence of hypertension, especially in the Banggai health center working area as the basis for determining the priorities and targets of local government interventions.

## METHODS

This research is an analytical observational study with a case control design. Researchers involved 140 people which are grouped in two, namely case and control groups, totaling 70 people each in the Banggai Community Health Center working area. The number of samples was calculated using the Stanly Lameshow formula (with a proportion of 50% and 95% Confidence Intervals) and selected with simple random sampling method.

The variables in this study were the incidence of hypertension, age, family history of hypertension, obesity status, smoking status, coffee consumption habits, use of hormonal birth control, and place of residence. Data on the incidence of hypertension uses secondary data based on Banggai Health Center medical records. Respondents' age was grouped into at risk (≥ 36 years) and not at risk (< 36 years). Family history of hypertension was grouped into having a history and having no history. This grouping is based on a history of hypertension in the respondent's mother or father. Obesity status was grouped into obese and non-obese based on BMI calculations. Smoker status was grouped into smokers (smoking at least once per week/month) and non-smokers. The habit of consuming coffee is based on the frequency of coffee consumption. Hormonal birth control use was defined as a history of using injection, PIL, and implant types of birth control. Places of residence are grouped into mountainous areas and coastal areas. This grouping is based on geographic conditions (height above sea level).

Data were collected on age, family history of hypertension, smoking status, coffee consumption habits, use of hormonal birth control, and place of residence using the interview method using a questionnaire. BMI data is the result of calculations using weight and height data collected based on direct measurement results. Height measurement using microtoise. Body weight is measured using a digital scale that has been calibrated first. Approval for data collection was obtained from the Banggai

Investment and One-Stop Integrated Service Department (Letter of Approval's number: 14.5.14/570/DPMPTSP/V/2023) on May 9, 2023.

Data analysis uses univariate, bivariate and multivariate analysis. First, a data normality test was carried out. Second, analysis of the characteristic variables was carried out univariate and bivariate analysis based on the results of the data normality test. The chi-square test were conduct in bivariate analysis. Variables with abnormal data distribution will be analyzed using non-parametric tests. Variables with a significant value ($\rho<0.25$) will be included in the multivariate analysis with multiple logistic regression tests using the backward LR method. With this method, the multivariate analysis of potential predictors is carried out in stages. Thus, researchers can also consider the existence of confounding variables that must be adjusted in a prediction model. Data analysis is processed using the IBM SPSS Statistics Grad Pack 29.0 program with license number 415f83f0c508a0658f31. Confounding variables were controlled by two ways. First, by conduct the sample randomized procedure. And second, by ajusted the potential convounder in the logistic regression.

## RESULT

A total of 140 people were involved in this study. Most of them were female (90 people (70%)), aged ≥36 years (90 people (64.3%)), did not have a family history of hypertension (72 people (51.4%)), were normal of BMI (71 people (50.7%), did not smoke (107 people (76.4%)), consumed coffee (84 people (60%)), used hormonal contraceptives (78 people (55.7%)) and lived in coastal areas (118 people (84.3%)). The description of these characteristics will be different between the hypertension group and the control group.

The results of this study showed both the case and control groups were mostly female (64.5% and 75.5%), no smoking (78.6% and 74.3%), had Consuming of Coffee (64.3% and 55.7%), Hormonal contraceptive used (60% and 51.4%) and lived in the Coastal areas (82.9% and 85.7%). The characteristics distribution are not significant different between case and control group (($\rho>0.05$). Meanwhile, age, family history of hypertension and Body Mass Index differed between the case and control groups. In the case group, most were aged ≥36 years (82.9%), had a family history of hypertension (78.6%) and were obese (60%). On the contrary, In the control group, most were aged <36 years (54.3%), hadn't a family history of hypertension (81.4%) and were normal in BMI (61.4%). The result of bivariat analysis., the different are significat with $\rho<0.05$

**Table 1. Comparison of demographic characteristics, BMI, smoking behavior, coffee consumption Habits, and use of hormonal contraceptives in the case and control groups.**

| Characteristics | Case Group | Control Group | Total Groups | ρ |
|---|---|---|---|---|
| | Frequency (%) | | | |
| Sex | | | | |
| Male | 25 (37.5) | 17 (24.3) | 42 (30.0) | 0.142 |
| Female | 45 (64.3) | 53 (75.7) | 98 (70.0) | |
| Age* | | | | |
| ≥36 years | 58 (82.9) | 32 (45.7) | 90 (64.3) | 0.001 |
| <36 years | 12 (171) | 38 (54.3) | 50 (35.7) | |
| Family history of hypertension* | | | | |
| Have a history | 55 (78.6) | 13 (18.6) | 68 (48.6) | 0.001 |
| Not Have History | 15 (21.4) | 57 (81.4) | 72 (51.4) | |
| Body Mass Index (BMI)* | | | | |
| Obesity | 42 (60.0) | 27 (38.6) | 69 (49.3) | 0.012 |
| Normal | 28 (40.0) | 43 (61.4) | 71 (50.7) | |
| Smoking Status | | | | |
| Smoker | 15 (21.4) | 18 (25.7) | 33 (23.6) | 0.551 |
| No | 55 (78.6) | 52 (74.3) | 107 (76.4) | |

| Characteristics | Case Group | Control Group | Total Groups | ρ |
|---|---|---|---|---|
| | Frequency (%) | | | |
| Consumption of Coffee | | | | |
| Consuming of Coffee | 45 (64.3) | 39 (55.7) | 84 (60.0) | 0.301 |
| No | 25 (35.7) | 31 (44.3) | 56 (40.0) | |
| Use of hormonal contraceptives | | | | |
| Hormonal contraceptive used | 42 (60.0) | 36 (51.4) | 78 (55.7) | 0.308 |
| No | 28 (40.0) | 34 (48.6) | 62 (44.3) | |
| Geographic location | | | | |
| Coastal areas | 58 (82.9) | 60 (85.7) | 118 (84.3) | 0.643 |
| Mountainous areas | 12 (17.1) | 10 (14.3) | 22 (15.7) | |

*) p<0.05 have a statistical significant relationship

The results of this research show in partially. the variables age. family history of hypertension and BMI have a statistically significant relationship with the incidence of hypertension. Where people aged ≥ 36 years tend to experience hypertension compared to those aged <36 years. Likewise. people with a family history of hypertension are more likely to experience hypertension. On the other hand. those who do not have a history are less likely to experience hypertension. The BMI variable also shows the same trend. Where those who are obese tend to develop hypertension. There are had statistically significant relationships with Hypertension (ρ<0.05). Thus. the Age. Family history of hypertension. and Body Mass Index were used in the multivariate analysis to evaluate their impact on Hypertension incidence.

In addition. sex showed a significance value of 0.142. which also met the requirements for incorporation into the multivariate analysis (variable with ρ<0.25). Likewise. although the significant value for smoking status was > 0.05. based on expert knowledge considerations. this variable was also included in the multivariate analysis. Finally. we had five variables as a candidate for the multivariate analysis stage. There are Sex. Age. family history of hypertension. Body Mass Index and smoking status.

Interaction tests were evaluated. The analysis findings showed that there were no significant relationships between sex and smoking status to Hypertension incidence. It is mean there are no interactions between sex and smoking status. Likewise. there is no interaction between BMI and smoking status in relation to hypertension.

In the first regression model there are two variables with a ρ <0.05. namely Age and family history of hypertension. while other variables have a ρ > 0.05. Namely sex (0.087) Body Mass Index (0.217) and smoking status (0.188). Next. using the enter method. each variable with a ρ > 0.05 is removed one by one starting from the variable with the highest significance value. namely the BMI. smoking status and sex variables.

However. when the BMI variable was excluded there was a difference in coefficient B > 10% in the smoking status variable. So BMI is declared as confounding in this prediction model and must still be included in the model. Likewise. when smoking status is excluded. there is a difference in coefficient B> 10% on the sex variable. And finally. when the sex variable was removed from the model. the difference in coefficient B was >10% in the smoking status variable. Based on that. it was found that Sex. BMI and Smoking status were to be significant confounding factors. Therefore. these confounding variables are still included in the model.

**Table 2. Multivariate Analysis of Hypertension Incidence Prediction Model**

| Models | Variables | Coeff (β) | ρ | Exp(β) | 95% CI | R Square |
|---|---|---|---|---|---|---|
| **Fisrt Models** | Constant | -7.127 | 0.001 | 0.001 | | 0.593 |
| | Sex | 1.966 | 0.087 | 7.140 | 0.752-67.827 | |
| | Age | 2.365 | 0.001 | 10.645 | 3.422-33.117 | |
| | Family history of hypertension | 3.244 | 0.001 | 25.633 | 8.662-75.848 | |

| Models | Variables | Coeff (β) | ρ | Exp(β) | 95% CI | R Square |
|---|---|---|---|---|---|---|
| | BMI | 0.592 | 0.217 | 1.808 | 0.706-4.631 | |
| | Smoking Status | 1.588 | 0.188 | 4.895 | 0.460-52.068 | |
| **Final Models** | Constant | -7.127 | 0.001 | 0.001 | 0.752-67.827 | 0.593 |
| | Sex | 1.966 | 0.087 | 7.140 | 3.422-33.117 | |
| | Age | 2.365 | 0.001 | 10.645 | 8.662-75.848 | |
| | Family history of hypertension | 3.244 | 0.001 | 25.633 | 0.706-4.631 | |
| | BMI | 0.592 | 0.217 | 1.808 | 0.460-52.068 | |
| | Smoking Status | 1.588 | 0.188 | 4.895 | 0.752-67.827 | |

The final regression model included Sex. Age. family history of hypertension. Body Mass Index and smoking status. where the incidence of hypertension in this study could be predicted by 59.3% by these variable and another 40.7% is explained by other variables not examined in this study. This model is declared FIT (the various independent variables included in this model are appropriate for describing the incidence of hypertension). This is indicated by the significance value of the omnibus test of coefficient model < 0.05. Family history of hypertension is the most dominant variable in the incidence of hypertension. where those who have a history are 25.6 times more likely to develop hypertension than those who do not have a history.

## DISCUSSION

The prediction model in this study is based on the results of multivariate logistic regression analysis. Where this prediction model involves the variables Sex. Age. family history of hypertension. Body Mass Index and smoking status. the model could be predicted hypertension incidence by 59.3%. Family history of hypertension is the most dominant variable in the incidence of hypertension. where those who have a history are 25.6 times more likely to develop hypertension than those who do not have a history (ρ< 0.001).

Hypertension tends to be a hereditary disease.A research result shows an individual's risk of experiencing hypertension based on family history of hypertension. A person will have a greater chance of developing hypertension if their parents suffer from hypertension. If one of the parents suffers from hypertension then that person has a 25% chance of suffering from hypertension throughout their life.[9] And if both parents suffer from hypertension. the possibility of experiencing hypertension is 60%. The results of this study are also in line with research conducted by Black & Hawks (2015) that someone who has a family history of hypertension will have a greater risk of developing hypertension.[10]

In this study. most respondents had a family history of hypertension. It was found that there was a significant relationship between family history and the incidence of hypertension in the Banggai Community Health Center Work Area. This happens because someone who has a family history of hypertension. some of their genes will interact with the environment and cause an increase in blood pressure. Likewise. research conducted by Mamuaya in 2017 stated that there was a significant relationship between family history and the incidence of hypertension.[11] One is through the mechanism of gene involvement in the renin-angiotensin-aldosterone system. That variations in them might impair blood pressure control and contribute to hypertension. Another mechanism is about the relationship of genes to the normal function of the blood vessel lining (vascular endothelium). Changes in genes can result in increased blood pressure because blood vessels are abnormally constricted or narrowed.[12–15] If this is allowed to run naturally without any intervention. the addition of environmental factors will cause hypertension to cause signs and symptoms.[16]

Age is also a factor that affects blood pressure. The older a person is. the greater the risk of experiencing hypertension.[17] In this study. most respondents were in the risk age group (≥36 years). The results of the bivariate analysis obtained 82.9% of respondents who experienced hypertension were ≥36 years old. In contrast. in the control group. most respondents were <36 years old. which

was 54.3%. The difference in the distribution of characteristics in the two groups was statistically significant (ρ<0.05). The findings of this analysis suggest a notable correlation between age and the occurrence of hypertension in the Banggai Health Center Work area. As individuals age. there is a decline in the function of the body's organs. which encompasses the cardiovascular system. comprising the heart and blood vessels. This is in line with the theory that increasing age causes physiological changes in the body. one of which is thickening of the artery walls due to the accumulation of collagen in the muscle layer. so that blood vessels narrow and become stiff. this begins when entering the age of 45 years. It is also caused by changes in the structure of large blood vessels. so that the lumen will narrow and the walls of the blood vessels will become stiffer. this results in increased systolic blood pressure. The aortic regurgitation along with the existence of degenerative processes. is also more prevalent at that age.[18–20]

In this study. it was found that the risk of experiencing hypertension was greater in the age group ≥ 36 years. People aged ≥ 36 years are at risk of developing hypertension 10.645 times greater than those aged < 36 years. This is in line with research conducted by Tjekyan (2017) stating that the older you get. the risk of developing hypertension is 6.1 times higher.[21] Also research conducted by Ningsih at al (2017) who conducted research on Beringharjo Market workers. Yogyakarta City. which found that age was correlated to the incidence of hypertension (ρ = 0.001) with OR= 15.706 (95% CI 3.615-68.230). This implies that as a person ages. their likelihood of developing hypertension increases.[22]

High blood pressure is often found in groups who are obese compared to groups whose body mass index is normal.[23] In this study. most of the respondents who experienced hypertension also experienced obesity (60%). The bivariate analysis conducted with the regression test showed ρ=0.012 (ρ< 0.05). The results of this analysis show that there is a significant relationship between BMI and the incidence of hypertension in the Banggai Community Health Center Work Area. This is because someone who is obese will need a lot of blood to supply oxygen and food to the body's tissues. thus the volume of blood circulating in a person's blood vessels will also increase so that the heart's work will also become faster. resulting in an increase in blood pressure This is in line with the theory that being overweight or obese can lead to hypertension. both directly and indirectly mechanisms. Obesity can directly cause an increase in cardiac output because the greater the body mass. the greater the amount of blood circulating so that cardiac output also increases. Meanwhile. indirectly through stimulation of the activity of the sympathetic nervous system and the Renin Angiotensin Aldosterone System (RAAS) by mediators such as hormones. cytokines. adipokines and so on. One of them is the hormone aldosterone which is closely related to water and sodium retention so that blood volume increases.

According to Nugraheni et al. (2019) stated that people who weigh more generally have difficulty moving freely. whereas to be able to move their body. the heart has to pump blood and make blood pressure rise.[24] A weight gain of around 2 kg can put a person at risk of increasing blood pressure as well. This research is in line with research conducted by Kembuan et al (2015) which stated that the relationship between obesity and the incidence of hypertension are significant. This occurs due to enhanced heart performance in obese individuals. leading to a rise in blood volume and pressure against the arterial walls.[25]

The results of multivariate analysis using the Multiple Logistic Regression test obtained OR BMI = 1.808. where respondents who are obese have a 1.8 times greater risk of experiencing hypertension compared to respondents who are not obese. This is in line with research conducted by Natalia. D in 2015 which stated that people who are obese have a risk of developing hypertension that is 2.1 times higher than people who have a normal weight.[26] Research also conducted by Agnesia in 2012 also showed that people who are obese have a risk of developing hypertension 9 times greater than people who are not obese.[27]

Smoking is also a factor that causes diseases of the blood vessels. heart and increased blood pressure. A person who smokes cigarettes will increase their heart rate by up to 30%. Cigarettes contain nicotine which causes dependence and can stimulate the release of adrenaline so that the heart works faster and stronger. ultimately resulting in an increase in blood pressure.[28] In this study. both the case and control groups were mostly non-smokers. results of multivariate analysis. obtained OR=4.895. This means that the group that smokes has a 4.9 times greater risk of developing hypertension than those who do not smoke.

The limitation of this study is that the status of hypertension events uses secondary data and is not primary data from direct blood pressure examinations of respondents. The validity of the measurement cannot be ascertained. so that there is potential for errors in the research results. Therefore. direct blood pressure measurement is needed in further research. In addition. more respondents live in coastal areas compared to mountainous areas. This is because the Banggai Health Center's working area has 3 sub-districts and 2 villages in coastal areas. Meanwhile. in mountainous areas there is only 1 village. This can result in selection bias. So the results of the analysis show that the majority of hypertension sufferers are in coastal areas. This is contrary to theory and previous research results which state that those who live in mountainous areas are more at risk of developing hypertension. Most importantly. the biases in this study are related to the limitations of the study design. Prediction models ideally need longitudinal data to assess the valid causality. This retrospective design is generally constrained by recall bias.

In this study. it also cannot be determined how much individual risk is based on the regression equation model that has been produced. This is because the research design used is not a cohort study. For determined how much individual risk need additional potential variables (e.g.. diet. physical activity. stress level) also. that could enhance predictive accuracy.

## CONCLUSION

Sex, age, family history of hypertension, body mass index, and smoking status can predict the incidence of hypertension by 59.3% together, after adjusting for the covariates. The other unmeasured factors contribute to the remaining 40.7%. Family history of hypertension is the most dominant variable in the incidence of hypertension. This prediction model is beneficial in assessing the risk of hypertension for each individual and is a consideration in the early diagnosis of the disease and the provision of fast and appropriate treatment. To improve public health. To reduce the prevalence of hypertension. It is necessary to provide family-based health education (including how to predict and prevent risk factors, especially for individuals aged over 36 years with a family history of hypertension) and conduct screenings for non-communicable diseases by healthcare workers based on the identified prediction variables. In the future. More variables (e.g, diet., physical activity, stress level) need to be studied that could enhance predictive accuracy by considering prospective research designs and involving more samples. To ensure the resulting model is more valid and precise in predicting the incidence of hypertension.

**Author Contribution Statement:** Erni Yusnita Lalusu contributed to research planning, data processing and analysis, as well as writing this manuscript. Indah Papendang is responsible for collecting data and preparing research reports. Dwi Wahyu Balebu played a role in planning the research and preparing the report as well as adding to several parts of the discussion of this manuscript.

**Conflicts of Interest:** The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

**Statement of Funding Sources:** This research was funded independently and did not receive funding support from anywhere.

**Acknowledgment:** Acknowledgments to the Banggai Community Health Center for facilitating this research. and the enumerators from the Faculty of Public Health. Tompotika Luwuk University who helped in conducting the interviews.

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