# The Influence of The Severity of Obstructive Sleep Apnea on The Incidence of Hypertension

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**Abstract**

**Background :** Hypertension is a condition where systolic blood pressure reaches 140 mmHg, and diastolic blood pressure reaches 90 mmHg. According to the Ministry of Health of Republic Indonesia, hypertension ranks third as a cause of death in Indonesia. Secondary hypertension arises from identifiable causes such as obstructive sleep apnea, renal vascular disease, hormonal contraceptives, endocrine disorders, stress-induced hypertension, pregnancy, burns, renal parenchymal disease, polycystic ovarian syndrome, preeclampsia, and specific medications like NSAIDs and antidepressants. Previous studies have recorded 83% Hypertension patients had OSA. Despite these findings, there are still contradictions in the literature (7), indicating the need for further research to explore the relationship between OSA and hypertension, as well as the impact of different types of OSA on hypertension.

**Methods :** This research is an observational analytic study using a cross-sectional method. Medical status data and polysomnography results were collected from February to April 2024 at Siloam Hospitals Lippo Village. Data were processed using SPSS 23.0 and analyzed using the chi-square method. Significant variables will be further analyzed using logistic multivariate analysis.

**Result :** There was an influence of the severity of Obstructive Sleep Apnea on the incidence of hypertension at Siloam Hospitals Lippo Village (OR=15.4, 95%CI 3.477 – 68.216; p-value=0.001). Besides the influence of the severity of Obstructive Sleep Apnea, other variables such as gender, BMI ≥ 23 kg/m², and a history of diabetes mellitus also affected the incidence of hypertension.

**Conclusion :** The influence of the severity of Obstructive Sleep Apnea on the incidence of hypertension found in Siloam Hospitals Lippo Village.

## Introduction

Hypertension, defined by the World Health Organization (WHO) as a condition where systolic blood pressure reaches or exceeds 140 mmHg and diastolic blood pressure reaches or exceeds 90 mmHg,[1] predominantly affects the elderly but can occur across all age groups. In 2018, WHO reported that approximately 972 million individuals, constituting about 26.4% of the global population, were diagnosed with hypertension—a figure that continues to rise annually, reaching 29.2% by 2021. Globally, hypertension contributes to an estimated 9.4 million deaths annually. In Indonesia, hypertension ranks third as a cause of death after stroke and tuberculosis.[2] With a prevalence of 34.11%, Indonesia is fifth globally in hypertension cases, and this prevalence is expected to escalate, potentially affecting 1.5 billion individuals by 2025. Essential hypertension, which comprises around 90% of cases, lacks a clear identifiable cause, though several contributing factors have been identified. These include genetic predisposition, insulin resistance, gender, high salt and fat diet, advanced age, sedentary lifestyle, low potassium and calcium intake, obesity, smoking, alcohol consumption, and imbalances in vasodilation and vasoconstriction modulators. Additionally, the Renin-Angiotensin-Aldosterone System (RAAS) and sympathetic nervous system play significant roles in hypertension development.[3] In contrast, secondary hypertension arises from identifiable causes such as obstructive sleep apnea, renal vascular disease, hormonal contraceptives, endocrine disorders, stress-induced hypertension, pregnancy, burns, renal parenchymal disease, polycystic ovarian syndrome, preeclampsia, and specific medications like NSAIDs and antidepressants.[4]

Obstructive Sleep Apnea (OSA), characterized by recurrent upper airway collapse during sleep leading to decreased oxygen saturation and fragmented sleep, is classified by severity based on the apnea-hypopnea index (AHI). Mild OSA ranges from 5 to 15 AHI, moderate from 15 to 30, and severe exceeds 30.[5] The condition is associated with increased sympathetic nervous system activity due to repeated airway obstruction, potentially contributing to hypertension development. Research in Indonesia indicates an 83% prevalence of OSA and hypertension among study participants, despite these findings, there are still contradictions in the literature,[7] indicating the need for further research to explore the relationship between OSA and hypertension, as well as the impact of different types of OSA on hypertension.

To address these issues, our study aims to investigate the relationship between Obstructive Sleep Apnea severity and hypertension incidence at Siloam Hospitals Lippo Village, Tangerang. As well as the impact of different types of OSA on hypertension. Understanding these interconnections could provide valuable insights into managing and preventing hypertension, particularly in populations affected by OSA.

## Material And Methods

This study has been approved by the Ethics Committee of Faculty of Medicine, Pelita Harapan University with the approval number 019/K-LKJ/ETIK/2024.

*Participants and Study Design*

This study adopts an analytical research design, specifically employing a quantitative approach with a cross-sectional method to investigate the impact of Obstructive Sleep Apnea severity on hypertension. 52 data were obtained from patients suspected of having obstructive sleep apnea (OSA) at Siloam Hospital in Lippo Village from January to December 2022. Then data were sorted based on the inclusion and exclusion criteria, which are inclusion critreria; patients of Siloam Hospitals Lippo Village 2022, Patients who have polysomnography results, AHI ≥ 5 and exclusion criteria which are; history of Continuous Positive Airway Pressure usage, history of kidney disease and Stroke history. 4 samples were excluded, 2 of which did not have polysomnography results, and 2 among them had a history of CPAP use. As a result, the final number of research samples was 48.

*Operational Definition*

The severity of OSA was assessed using the AHI, a metric calculated from polysomnography that quantified the hourly occurrence of respiratory disturbances during sleep. Cases were classified as mild (5–14.9 episodes/hour) or moderate-severe (>15 episodes/hour). Hypertension was defined by systolic blood pressure measurements of ≥140 mmHg and/or diastolic values of ≥90 mmHg, or documented administration of antihypertensive agents such as diuretics, beta-blockers, and angiotensin-converting enzyme inhibitors. Age was recorded as a continuous variable representing years since birth, while Diabetes Mellitus was identified through clinical confirmation of impaired glycemic regulation. Overweight status adhered to the Asia-Pacific classification, determined by a BMI of ≥23 kg/m² derived from anthropometric data. Gender was categorized dichotomously as male or female. All variables were systematically extracted from clinical documentation to standardize data collection.

*Statistical Analysis*

Data collection will be conducted using medical status and polysomnography. Data analyzed using SPSS 23.0. The research data will be tested using the chi-square method to examine the independent factor (OSA) and the dependent factor (Hypertension). In this research confounding variables (age, gender, history of Diabetes Melitus and BMI ≥ 23 kg/m²) will be further analyzed using logistic multivariate analysis.

**Result**

From a total of 52 samples with indications of obstructive sleep apnea were collected, which were then selected based on inclusion criteria. Four samples were excluded: two due to lack of polysomnography results and two due to a history of CPAP usage. The final sample size for the study was 48 samples.

**Table 1.** Sample Characteristics

| Sample Characteristics | (n%) |
|---|---|
| **Gender** | |
| Men | 37 (71.1%) |
| Women | 11 (22.9%) |
| **Age (year)** | |
| ≥60 | 9 (18.8%) |
| <60 | 39 (81.3%) |
| **Body Mass Index ($Kg/m^2$)** | |
| ≥ 23 $Kg/m^2$ | 34 (70.8%) |
| < 23 $Kg/m^2$ | 14 (29.2%) |
| **Apnea Hypopnea Index** | |
| Moderate-Severe | 32 (66.7%) |
| Mild | 16 (33.3%) |
| **Hypertension Status** | |
| Yes | 33 (68.8%) |
| No | 15 (31.3%) |
| **History Diabetes Mellitus** | |
| Yes | 31 (64.6%) |
| No | 17 (35.4%) |

The majority of samples were male, comprising 77.1%, aged < 60 years at 81.3%, with BMI ≥ 23 $kg/m^2$ at 70.8%, having a history of Diabetes Mellitus at 64.6%, exhibiting moderate to severe AHI status at 66.7%, and having hypertension at 68.8%.

*Association of Severity Obstructive Sleep Apnea and Hypertension*

**Table 2.** Association of Severity Obstructive Sleep Apnea and Hypertension

| Hypertension Status and Related Factors | Yes n (%) | No n (%) | Total | OR | OR (95% CI, P) | P |
|---|---|---|---|---|---|---|
| **Apnea Hypopnea Index** | | | | | | |
| Moderate-Severe | 28 (84.8%) | 5 (15.2%) | 33 | 15.4 | (3.477-68.216, 0.001) | 0.001 |
| Mild | 4 (26.7%) | 11 (73.3%) | 15 | | | |
| **Gender** | | | | | | |
| Men | 31 (93.9%) | 6 (40%) | 37 | 23.25 | (3.984-135.682, 0.001) | 0.001 |
| Women | 2 (6.1%) | 9 (60%) | 11 | | | |
| **BMI** | | | | | | |
| ≥23 $Kg/m^2$ | 31 (93.9%) | 7 (46.7%) | 38 | 17.71 | (3.069-102.262, 0.001) | 0.001 |
| <23 $Kg/m^2$ | 2 (6.1%) | 8 (53.3%) | 10 | | | |
| **Age** | | | | | | |
| ≥60 | 7 (77.8%) | 2 (22.2%) | 9 | 1.750 | (0.318-9.644, 0.803) | 0.803 |
| <60 | 26 (66.7%) | 13 (33.3%) | 39 | | | |
| **History Diabetes Mellitus** | | | | | | |
| Yes | 28 (84.8%) | 3 (20%) | 31 | 22.4 | (4.600-109.085, 0.001) | 0.001 |
| No | 5 (15.2%) | 12 (80%) | 17 | | | |

*Association between Apnea Hypopnea Index and Hypertension Status*

In this study, 28 samples with moderate-severe AHI were found to have hypertension. Conversely, only 4 samples with mild AHI had hypertension. Based on the chi-square test examining the relationship between Apnea Hypopnea Index and hypertension, a Crude Odds Ratio of 15.4 was obtained. This indicates that subjects with moderate-severe Obstructive Sleep Apnea are 15.4 times more likely to experience hypertension compared to those with mild Obstructive Sleep Apnea, and the relationship between the severity of Obstructive Sleep Apnea and hypertension incidence is statistically significant (p-value = 0.001).

*Association between Gender and Hypertension Status*

In this study, 31 male samples were found to have hypertension. Conversely, only 2 female samples had hypertension. Based on the chi-square test examining the relationship between gender and hypertension, a Crude Odds Ratio of 23.25 was obtained. This indicates that males are 23.25 times more likely to experience hypertension compared to females, and the relationship between gender and hypertension status is statistically significant (p-value = 0.001).

*Association between BMI and Hypertension Status*

In this study, 31 samples with BMI ≥ 23 kg/m² were found to have hypertension. Conversely, only 2 samples with BMI < 23 kg/m² had hypertension. Based on the chi-square test examining the relationship between BMI and hypertension, a Crude Odds Ratio of 17.71 was obtained. This indicates that subjects with BMI ≥ 23 kg/m² are 17.71 times more likely to experience hypertension compared to those with BMI < 23 kg/m², and the relationship between BMI and hypertension incidence is statistically significant (p-value = 0.001).

*Association between Age and Hypertension Status*

In this study, 7 samples aged ≥ 60 years were found to have hypertension. Conversely, 28 samples aged < 60 years had hypertension. Based on the chi-square test examining the relationship between age and hypertension, a Crude Odds Ratio of 1.7 was obtained. However, the Crude Odds Ratio result was not statistically significant (p-value = 0.803).

*Association between History of Diabetes Mellitus and Hypertension Status*

In this study, 28 samples with a history of Diabetes Mellitus also had hypertension.

Conversely, only 5 samples without a history of Diabetes Mellitus had hypertension. Based on the chi-square test examining the relationship between Diabetes Mellitus history and hypertension, a Crude Odds Ratio of 22.4 was obtained. This indicates that subjects with a history of Diabetes Mellitus are 22.4 times more likely to experience hypertension compared to those without a history of Diabetes Mellitus, and the relationship between Diabetes Mellitus history and hypertension incidence is statistically significant (p-value = 0.001).

**Table 3.** Multivariate Analysis Results

| | Adjusted Odd Ratio | 95% CI | P-value |
|---|---|---|---|
| **Severity of OSA** | 4.53 | 1.312-605 | 0.033 |
| **Gender** | 5.39 | 1.751-735.8 | 0.02 |
| **BMI** | 4.44 | 1.378-6466 | 0.035 |
| **History of Diabetes Melitus** | 4.25 | 1.198-1149 | 0.039 |

In the multivariate logistic regression analysis, after adjusting for other variables, the severity of AHI remained associated with hypertension. The difference between the Crude Odds Ratio and the Adjusted Odds Ratio exceeded 10% for gender, BMI, and history of Diabetes Mellitus, indicating that these variables acted as confounders in this study. Additionally, gender, BMI, and history of Diabetes Mellitus were statistically significant (p-value < 0.05).

## Discussion

In this study, the patient sample consisted of 77% males and 23% females. The majority of the sample had moderate-severe AHI, comprising 32 subjects out of a total of 48. A study by Michel showed a similar distribution with 60.2% male and 39.8% female participants, and a majority of 70.6% had moderate-severe AHI.[7] Regarding hypertension status, 68.8% of the participants had hypertension, with 19% aged ≥60 years and 81% aged <60 years. This distribution is like the findings of Yunua, where 80% of the sample was aged <60 years and 20% aged ≥60 years, with 70% having hypertension.[8] In this study, 70.8% of the subjects had BMI > 23 and 29.2% had BMI < 23, and 64.6% had a history of diabetes mellitus. Studies by Tince and Jung Hwan Jo also showed a similar distribution with 20% of patients having a BMI < 23 and 65% having a history of diabetes mellitus.[9,10]

In this study, the severity of OSA was divided into two groups: mild and moderate-severe. Due to the small number of samples (severe = 6), the severe cases were combined with the moderate cases for analysis. The study found that the severity level of AHI > 15 was associated with a higher risk of hypertension, cardiovascular disease, and other health problems. This division also allowed researchers to focus on more severe cases of OSA, which are more likely to have a significant impact on the health and quality of life of patients. In this study, 66.7% of subjects had moderate-severe OSA and 33.3% had Mild OSA. In the analysis of the strength of the relationship, it was found that the severity of OSA severity had a strong association with the incidence of hypertension. This was evidenced by a crude OR of 15.4 with a p-value of 0.001, and an OR after controlling for gender, history of diabetes mellitus, and BMI still showed significant results (AOR = 4.53; p-value = 0.033). Studies by Grote et al. and Youte et al., which discussed the influence of the severity of OSA on the incidence of hypertension, also found a significant relationship with the severity of OSA on the incidence of hypertension, as evidenced by an increased OR found in Parati et al., obtained an OR of 6.84 for Moderate-Severe OSA with hypertension,[11] and in the study by Young found an increase in the incidence of hypertension, in mild OSA by 57% and 67% of moderate-severe OSA.[12] This is also supported by physiological theories, OSA can cause an increase in blood pressure due to increased sympathetic nervous activity, increased RAAS activity, and oxidative stress due to hypoxia conditions that occur during sleep.

Older age can influence the occurrence of OSA. According to Osorio et al., 50% of OSA cases occur in individuals aged ≥60 years, attributed to lax throat tissues and muscles causing increased pharyngeal resistance. Individuals aged

≥60 years tend to experience easier weight gain due to decreased physical activity and growth hormone, which subsequently increases fat accumulation by reducing lipolysis. Moreover, decreased sensitivity to thyroid hormones and leptin resistance contribute to decreased appetite suppression. This is one of the reasons why OSA is more prevalent in those aged ≥60 years. However, this study found that individuals aged <60 years' experience OSA more frequently than those aged ≥60 years. This finding aligns with Edward et al.'s research, suggesting it may be due to subjects aged ≥60 years having a tendency towards a non-overweight BMI. Hypertension is also more prevalent in those aged ≥60 years, as studies show that after the age of 60, the inhibitory effect of L-NMMA on acetylcholine response is weak, and Nitric Oxide availability is completely disrupted in the elderly population.[13-15]

In this study age groups were divided into <60 years and ≥60 years. According to RISKESDAS in 2018, 63.2% of those aged ≥60 years were found to have hypertension.[16,17] This is physiologically due to a decline in nitric oxide levels at 60 years of age. Nitric oxide is produced from the precursor L-Arginine, which is converted into nitric oxide with the help of Nitric Oxide Synthase enzymes, catalyzing the oxidation of five electrons from guanidino nitrogen L-arginine. However, in those aged ≥60 years, most studies on NO activity in cells and tissues agree that biological availability or generation of NO from NOS decreases with age. Vascular changes related to hypertension, such as endothelial dysfunction, accelerate with aging.[18-20] Additionally, the presence of acetylcholine along with NO synthase inhibitor (L-NMMA) was tested for NO availability in blood vessels. After the age of 60, the inhibitory effect of L-NMMA on acetylcholine response is very weak, indicating that NO availability is completely disrupted in the elderly population. Studies also indicate that subjects aged 60 years show decreased sensitivity in taste senses, especially to salty tastes, leading to increased use of flavor enhancers and high salt in consumed foods, which further increases the incidence of hypertension.[13]

In this study, subjects aged ≥60 years accounted for 18.8%, and <60 years accounted for 81.3%. Regarding the relationship, this study found that age ≥60 years is not associated with the occurrence of hypertension, although the crude OR obtained was 1.4, the OR obtained was not statistically significant (p-value = 0.8). The findings of the crude OR cannot indicate a relationship and may occur by chance. These findings do not align with physiological theories and other studies investigating sociodemographic factors influencing hypertension in aging. Studies by Etrin et al. and Aida et al. state that there is a significant relationship between age ≥60 years and the occurrence of hypertension. In Erin et al.'s study involving

757 samples and Aida et al. study involving 5,874 samples, Erin et al. obtained an adjusted odds ratio of 28.1 for age over 60 years with a p-value = 0.002, and Lydia et al. obtained a p-value of 0.001 after comparison with other variables and an adjusted odds ratio of 1.68. Both findings indicate that age ≥60 years has a higher risk compared to age <60 years for the occurrence of hypertension.[21,22] These findings are consistent with a study from Brazil that found age <60 years increases the risk of hypertension.[23] This is hypothesized to occur because subjects aged ≥60 years in the study had a better BMI compared to those aged <60 years. Additionally, this finding may be due to uneven age distribution, so subjects aged ≥60 years tend to be unrelated to the occurrence of hypertension (p-value = 0.803).

In this study, 24 OSA subjects were found to have diabetes mellitus. Diabetes mellitus and OSA have a significant relationship, but this does not imply that OSA is the cause of diabetes; it can be bidirectional and overlap. In a study by Mok et al., involving 30 patients with diabetes mellitus, glycemic control was performed, and after 5 days, there was a reduction in the severity of obstructive sleep apnea. Tince et al. also suggest that diabetes mellitus can cause OSA through mechanisms involving muscle tone reduction. Diabetes can cause nerve damage (neuropathy) that controls the muscles around the pharynx, leading to weakness and vulnerability to collapse during sleep. The study found a statistically significant relationship (p-value 0.045). Other studies also found that obstructive sleep apnea can worsen diabetes mellitus through intermittent hypoxia, which increases sympathetic activity and leads to chronic oxidative stress and inflammation. This contributes to glucose metabolism disorders. The adverse effects of hypoxia can also directly affect the function of pancreatic beta cells, liver, and adipose tissue, all of which are involved in glucose homeostasis.[24-26]

In this study, a significant relationship was found between diabetes mellitus and hypertension, with a crude OR of 22.4 and an OR adjusted for OSA severity, gender, and history of diabetes mellitus of 4.25, and this relationship is statistically significant ($p < 0.05$).In theory, diabetes mellitus is related to hypertension through insulin resistance, which increases sympathetic nerve activity, endothelial dysfunction, sodium and water resistance, increased RAAS activity, and increased production of clotting factors and inflammatory mediators that can damage blood vessels.[27] Studies by Guanghong et al. and Prisilia et al., examining the relationship between diabetes mellitus and hypertension, found that diabetes mellitus can increase the incidence of hypertension.[28] Jia et al. study found that 80% of subjects with diabetes mellitus had hypertension and had a 2- to 4-fold increased risk of hypertension.[29]

In this study, 28 OSA subjects had a BMI ≥23 kg/m². Jo et al. in Korea found that a BMI ≥23 kg/m² is associated with OSA. Jehan et al. in America found different results, showing that a BMI ≥25 kg/m² is associated with OSA. These differing findings may be due to ethnic differences. In Asian populations, BMI associated with OSA is lower compared to Caucasian populations, possibly due to smaller jaw size and higher airway collapsibility.[30,31] BMI in this study was divided into two groups: BMI ≥23 kg/m² and BMI < 23 kg/m² because BMI ≥23 kg/m² is considered the BMI threshold for hypertension risk defined by the Asia-Pacific region, specifically for Asia. However, only one study has researched cut-off points at a BMI of 22.4 kg/m², which is considered suitable for Indonesia. This lower threshold compared to Europe is due to the tendency of Asian populations to have a higher body fat percentage with a lower BMI compared to European populations. This is known as the Yudkin-Yajnik (Y-Y) paradox. Differences in body composition are thought to be related to a higher body fat percentage and prevalence of abdominal obesity in Asian populations, thereby increasing the risk of hypertension.[32-34]

In this study, 70.8% of subjects had a BMI ≥23 kg/m² and 29.2% had a BMI < 23 kg/m². In terms of strength of the relationship, BMI has a strong association with the occurrence of hypertension, as seen in the crude OR of 17.71 and the OR adjusted for OSA severity, gender, and history of diabetes mellitus of 4.44, and this relationship is statistically significant ($p < 0.05$).

In theory, BMI is related to hypertension through activation of the sympathetic nervous system, intra-abdominal and intra-vascular fat amounts, kidney sodium retention leading to increased reabsorption, changes in cytokine derivatives (leptin and hyperinsulinemia), and renin-angiotensin system, which are considered to play an important role in the pathogenesis of obesity-related hypertension.[35] Studies by Hong Seok Lee et al., Fariha et al., and Asyafah et al., looking at the relationship between BMI ≥23 kg/m² and hypertension, found that BMI is significantly associated with hypertension. All three studies also found that subjects with BMI ≥23 kg/m² had an increased risk of hypertension and found a p-value <0.05, further demonstrating the strong association between BMI ≥23 kg/m² and hypertension.[36,37]

In this study, 28 samples with OSA were found to be male. Men have a higher prevalence of OSA compared to women, with a study explaining that the prevalence ratio of men affected by OSA compared to women is as high as 3:1. This is due to physiological differences where estrogen can help maintain airway patency by increasing upper respiratory muscle activity and differences in fat distribution (in males, fat distribution is visceral, whereas in females, it is peripheral; visceral fat accumulation around the neck and chest can compress the airway, especially during sleep when throat muscles relax). Pressure from visceral fat can narrow or block the airway, triggering apnea episodes or reduced airflow during sleep. The length of the upper respiratory tract is found to be higher in males than in females, which is associated with a higher tendency for airway collapse. In the study by Duarte et al., it was found that being male is associated with the occurrence of OSA (p-value <0.001).[38] In this study, there were 37 male subjects and 11 female subjects. Regarding their relationship, it turns out that being male has a strong association with the occurrence of hypertension, as seen from the crude OR of 23 and the OR adjusted for OSA severity, history of diabetes mellitus, and BMI of 5.3, which is statistically significant ($p < 0.05$).

In theory, males tend to have a higher incidence of hypertension compared to females. However, when females reach menopause, estrogen levels tend to decrease, and the risk of hypertension becomes similar to that of males. Estrogen can stimulate the production of nitric oxide (NO), which is a protective mechanism against hypertension. Nitric oxide is a naturally produced vasodilator that controls vascular tone and thus regulates blood pressure. However, menopause does not have a precise age range but generally begins around age 45 and ends around age 65.[39,40]

Research by Falah et al. and Deffiana et al., examining sociodemographic factors influencing the occurrence of hypertension, found that hypertension is more likely to occur in males. Deffiana et al.'s study in Indonesia showed that males have an increased risk of hypertension compared to females.[41,42] However, in a study by Kusumawaty et al., a comparison found that 58% were females and 42% were males suffering from hypertension. These differing findings are due to the age of the population used in the study. The subjects used in the study were mostly over 60 years old.[43] As explained earlier, women over the age of 60 experience menopause, which ultimately leads to estrogen loss, reducing the risk factor for hypertension.

**Multivariate Analysis**

Multivariate analysis was conducted to determine whether variables that were found to be significant in bivariate testing maintained their significance when controlled for other variables. Variable selection was performed after bivariate analysis, focusing on variables with P-values ≤ 0.25. These variables were further analyzed using multivariate logistic regression analysis. They were considered suitable candidates for inclusion in the multivariate logistic regression analysis. The candidate variables for analysis included the severity of OSA, gender, BMI, and history of diabetes mellitus.

In the multivariate analysis, gender was found to be the most significant variable contributing to hypertension. This may be due to most of the samples being male, with hypertension more likely to occur in males than females. Additionally, the severity of OSA was observed to still be associated with hypertension. The crude odds ratio obtained was 15.4, which changed to 4.53 after controlling other variables. The difference in OR values is hypothesized to be because each variable included in the multivariate analysis has a strong relationship and acts as a confounding factor. Gender, severity of OSA, BMI, and history of diabetes mellitus were identified as confounding factors, evidenced by the difference in crude OR and adjusted OR >10% for these variables. OR >1 obtained for gender, severity of OSA, BMI, and history of diabetes mellitus indicates a statistically significant association with hypertension (p-value <0.05).

### Strengths and Limitations of the Study

Based on the data and discussions provided, obstructive sleep apnea (OSA) being one of the contributing factors. Studies have established a link between OSA and hypertension. While studies have established a link between OSA and hypertension, some research shows conflicting results and does not thoroughly explore the impact of OSA severity on hypertension incidence. Therefore, this study's focus on OSA severity is a significant strength. Additionally, this study employed multivariate analysis to assess the strength of the relationship between OSA and hypertension after controlling other variables. However, a notable limitation of this study is the small sample size, which may impact on the generalizability of the findings and reduce the statistical power of the analysis.

### Conclusion

In conclusion, there is a significant influence of the severity of Obstructive Sleep Apnea (OSA) on the occurrence of hypertension at Siloam Hospitals Lippo Village, after adjusting for the three variables.

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## References

1. World Health Organization. Hypertension [Internet]. 2023 [cited 2023 Nov 18]. Available from: https://www.who.int/news-room/fact-sheets/detail/hypertension
2. Kementerian Kesehatan Republik Indonesia. Fakta dan Angka Hipertensi [Internet]. 2017 [cited 2023 Nov 9]. Available from: https://p2ptm.kemkes.go.id/kegiatan-p2ptm/subdit-penyakit-jantung-dan-pembuluh-darah/fakta-dan-angka-hipertensi
3. Kementerian Kesehatan Republik Indonesia. Klasifikasi Hipertensi. 2018.
4. Pedrosa RP, Drager LF, Gonzaga CC, Sousa MG, de Paula LKG, Amaro ACS, et al. Obstructive Sleep Apnea. Hypertension. 2011 Nov; 58(5): 811–7. https://doi.org/10.1161/hypertensionaha.111.179788
5. Goyal M, Johnson J. Obstructive Sleep Apnea Diagnosis and Management. Mo Med. 2017;114(2):120–4. https://pmc.ncbi.nlm.nih.gov/articles/PMC6140019/
6. Dempsey JA, Veasey SC, Morgan BJ, O'Donnell CP. Pathophysiology of sleep apnea. Physiol Rev. 2010 Jan;90(1):47–112. https://doi.org/10.1152/physrev.00043.2008
7. Benin M. The Severity of Obstructive Sleep Apnea and Hypertension Among Middle aged Asians. Walden Dissertations and Doctoral Studies. 2015: 1772. https://scholarworks.waldenu.edu/dissertations/1772
8. Kadarullah O, Annisa Y. Pengaruh Obstructive Sleep Apnea (OSA) Terhadap Terjadinya Hipertensi Di Poli Saraf RSUD Prof. Dr. Margono Soekarjo. Sainteks. 2016; 13(2): 11-20. https://dx.doi.org/10.30595/sainteks.v13i2.1500
9. Nalle TS, Putra DG. Hubungan diabetes mellitus dengan obstructive sleep apnea (OSA) di Gedung Mario Tabanan, Bali-Indonesia. Intisari Sains Medis. 2021; 12(1): 88–91. https://www.isainsmedis.ejournals.ca/index.php/ism/article/view/884/742
10. Jo JH, Park JW, Jang JH, Chung JW. Polysomnographic and Cephalometric Evaluation of Patients with Obstructive Sleep Apnea According to Obesity Level. J Oral Med Pain. 2022 Sep 30;47(3):135–43. https://doi.org/10.14476/jomp.2022.47.3.135
11. Parati G, Lombardi C, Hedner J, Bonsignore MR, Grote L, Tkacova R, et al. Recommendations for the management of patients with obstructive sleep apnoea and hypertension. European Respiratory Journal. 2013 Mar; 41(3): 523–38. https://doi.org/10.1183/09031936.00226711
12. Young T, Peppard P, Palta M, Hla KM, Finn L, Morgan B, Skatrud J. Population-Based Study of Sleep-Disordered Breathing as a Risk Factor for Hypertension. Arch Intern Med. 1997 Aug 11; 157(15): 1746-1752. https://sleepcohort.wisc.edu/wp-content/uploads/sites/1452/2020/10/htn.pdf

13. Subkhi M. Hubungan pola makan dengan kejadian hipertensi pada lansia di Posyandu Mawar Desa Sangubanyu Kabupaten Purworejo [Tesis]. Yogyakarta: Universitas 'Aisyiyah Yogyakarta; 2016.
14. Edwards BA, Wellman A, Sands SA, Owens RL, Eckert DJ, White DP, et al. Obstructive Sleep Apnea in Older Adults is a Distinctly Different Physiological Phenotype. Sleep. 2014 Jul 1; 37(7): 1227-1236. https://doi.org/10.5665/sleep.3844
15. Osorio RS, Martínez-García MÁ, Rapoport DM. Sleep apnoea in the elderly: a great challenge for the future. European Respiratory Journal. 2022 Apr; 59(4): 2101649. https://doi.org/10.1183/13993003.01649-2021
16. Lydia A, Setiati S, Soejono CH, Istanti R, Marsigit J, Azwar MK. Prevalence of prehypertension and its risk factors in midlife and late life: Indonesian family life survey 2014–2015. BMC Public Health. 2021 Dec 12; 21(1) :493. https://doi.org/10.1186/s12889-021-10544-y
17. Oktamianti P, Kusuma D, Amir V, Tjandrarini DH, Paramita A. District-Level Inequalities in Hypertension among Adults in Indonesia: A Cross-Sectional Analysis by Sex and Age Group. Int J Environ Res Public Health. 2022 Oct 14; 19(20): 13268. https://doi.org/10.3390/ijerph192013268
18. Shannon OM, Clifford T, Seals DR, Craighead DH, Rossman MJ. Nitric oxide, aging and aerobic exercise: Sedentary individuals to Master's athletes. Nitric Oxide. 2022 Aug;125–126: 31–39. https://doi.org/10.1016/j.niox.2022.06.002
19. Torregrossa AC, Aranke M, Bryan NS. Nitric oxide and geriatrics: Implications in diagnostics and treatment of the elderly. Journal of Geriatric Cardiology. 2012 Jan 13; 8(4): 230–242. https://doi.org/10.3724/sp.j.1263.2011.00230
20. Sverdlov AL, Ngo DTM, Chan WPA, Chirkov YY, Horowitz JD. Aging of the Nitric Oxide System: Are We as Old as Our NO? J Am Heart Assoc. 2014 Aug 15;3(4): e000973. https://doi.org/10.1161/JAHA.114.000973
21. Linggar EZ, Irwan, Yunita M, Ruspanah I, Kadun A, Starlia F, Malakauseya M, Siahaya N. Prevalence and Factors Associated with Hypertension in the Coastal Com- munity of Laha Village: A Cross-Sectional Study. Nusantara Science and Technology Proceedings, 1st International Conference on Health and Medicine. 2023. https://doi.org/10.11594/nstp.2023.3510
22. Lydia A, Setiati S, Soejono CH, Istanti R, Marsigit J, Azwar MK. Prevalence of prehypertension and its risk factors in midlife and late life: Indonesian family life survey 2014–2015. BMC Public Health. 2021 Dec 12; 21(1) :493. https://doi.org/10.1186/s12889-021-10544-y
23. Silva MdS, Poyares D, Silva LO, Souza KM, Andersen ML, Ohayon MM, et al. Associations of the Severity of Obstructive Sleep Apnea With Age-Related Comorbidities: A Population-

Based Study. Front Neurol. 2022 May 10; 13: 802554. https://doi.org/10.3389/fneur.2022.802554

24. Reutrakul S, Mokhlesi B. Obstructive Sleep Apnea and Diabetes. Chest. 2017 Nov; 152(5): 1070–86. https://doi.org/10.1016/j.chest.2017.05.009
25. Nalle TS, Putra DG. Hubungan diabetes mellitus dengan obstructive sleep apnea (OSA) di Gedung Mario Tabanan, Bali-Indonesia. Intisari Sains Medis. 2021; 12(1): 88–91. https://www.isainsmedis.ejournals.ca/index.php/ism/article/view/884/742
26. Mok Y, Tan C, Wong H, How C, Tan K, Hsu P. Obstructive sleep apnoea and Type 2 diabetes mellitus: are they connected? Singapore Med J. 2017 Apr; 58(4): 179–83. https://doi.org/10.11622/smedj.2017027
27. Epstein M, Sowers JR. Diabetes Mellitus and Hypertension. Hypertension. 1992; 19(5): 403-18. https://doi.org/10.1161/01.hyp.19.5.403
28. Oktaviyani P, Salman, Sari MH, Frisilia M, Munazar, Satria A, Maretalinia. Prevalence and Risk Factors of Hypertension and Diabetes Mellitus among the Indonesian Elderly. Makara Journal of Health Research. 2022 Apr 26; 26(1): 7-11. https://doi.org/10.7454/msk.v26i1.1329
29. Jia G, Sowers JR. Hypertension in Diabetes: An Update of Basic Mechanisms and Clinical Disease. Hypertension. 2021 Nov; 78(5): 1197–205. https://doi.org/10.1161/hypertensionaha.121.17981
30. Jehan S, Zizi F, Pandi-Perumal SR, Wall S, Auguste E, Myers AK, et al. Obstructive Sleep Apnea and Obesity: Implications for Public Health. Sleep Med Disord. 2017; 1(4): 00019. https://pubmed.ncbi.nlm.nih.gov/29517065/
31. Jo JH, Park JW, Jang JH, Chung JW. Polysomnographic and Cephalometric Evaluation of Patients with Obstructive Sleep Apnea According to Obesity Level. J Oral Med Pain. 2022 Sep 30;47(3):135–43. https://doi.org/10.14476/jomp.2022.47.3.135
32. Mulyasari I, Afiatna P, Maryanto S, Aryani AN. Indeks Massa Tubuh (IMT) Sebagai Prediktor Hipertensi: Perbandingan Standar WHO dan Asia-Pasifik. Amerta Nutrition. 2023 Dec 31; 7(2SP): 247–51. http://dx.doi.org/10.20473/amnt.v7i2SP.2023.247-251
33. Nguyen TT, Adair LS, Suchindran CM, He K, Popkin BM. The association between body mass index and hypertension is different between East and Southeast Asians. Am J Clin Nutr. 2009 Jun; 89(6): 1905–12. https://doi.org/10.3945/ajcn.2008.26809
34. Shakeri N, Azizi F. Estimating the Cutoff Points of Time-Dependent Risk Factors by Using Joint Modeling of Longitudinal and Time-to-Event Data: A 14-Year Follow-up Study-Tehran Lipid and Glucose Study. Asia Pac J Public Health. 2019 Nov;31(8): 728-736. https://doi.org/10.1177/1010539519889767

35. Shariq OA, McKenzie TJ. Obesity-related hypertension: a review of pathophysiology, management, and the role of metabolic surgery. Gland Surg. 2020 Feb; 9(1): 80–93. https://doi.org/10.21037/gs.2019.12.03
36. Lee SH, Park YM, Han K, Yang JH, Lee S, Lee S, et al. Obesity-related hypertension: Findings from The Korea National Health and Nutrition Examination Survey 2008–2010. PLoS One. 2020 Apr 21; 15(4): e0230616. https://doi.org/10.1371/journal.pone.0230616
37. Hossain FB, Adhikary G, Chowdhury AB, Shawon MdS. Association between body mass index (BMI) and hypertension in south Asian population: evidence from nationally representative surveys. Clin Hypertens. 2019 Dec 15; 25: 28. https://doi.org/10.1186/s40885-019-0134-8
38. Duarte RLM, Magalhães-da-Silveira FJ, Gozal D. Sex-dependent GOAL screening performance in adults at risk for obstructive sleep apnea. Pulmonology. 2024 May; 30(3): 265–71. https://doi.org/10.1016/j.pulmoe.2022.01.004
39. Reckelhoff JF. Gender Differences in the Regulation of Blood Pressure. Hypertension. 2001 May; 37(5):1199–208. https://doi.org/10.1161/01.hyp.37.5.1199
40. Bryan NS. Nitric oxide deficiency is a primary driver of hypertension. Biochem Pharmacol. 2022 Dec; 206: 115325. https://doi.org/10.1016/j.bcp.2022.115325
41. Defianna SR, Santosa A, Probandari A, Dewi FST. Gender Differences in Prevalence and Risk Factors for Hypertension among Adult Populations: A Cross-Sectional Study in Indonesia. Int J Environ Res Public Health. 2021 Jun 9;18(12):6259. https://doi.org/10.3390/ijerph18126259
42. Falah M. Hubungan Jenis Kelamin Dengan Angka Kejadian Hipertensi Pada Masyarakat Di Kelurahan Tamansari Kota Tasikmalaya. 2019 May; 3(1): 85-94. https://doi.org/10.54440/jmk.v3i1.67
43. Kusumawaty J, Hidayat N, Ginanjar E. Hubungan Jenis Kelamin dengan Intensitas Hipertensi pada Lansia di Wilayah Kerja Puskesmas Lakbok Kabupaten Ciamis. Mutiara Medika. 2016 Jul; 16(2): 46-51. https://doi.org/10.18196/mmjkk.v16i2.4450

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