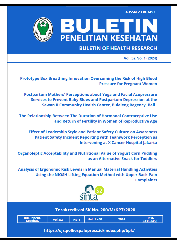

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Factors Associated with Hypertension among Selected Occupational Groups in Medan City, North Sumatra, Indonesia

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ABSTRACT
Background: Hypertension is one of the non-communicable diseases whose prevalence continues to increase and is a major risk factor for heart disease and stroke. This study aims to analyse the relationship between several risk factors, namely age, gender, marital status, education, family history, physical activity, stress, work environment, and diet, and the incidence of hypertension among fishermen, lecturers/employees, and street vendors in Medan City.
Methods: This study employed a cross-sectional design with a sample size of 176 respondents selected through purposive sampling. Data were collected via questionnaires and blood pressure measurements, then analysed using the chi-square test.
Results: The results of the study indicate that age (p = <0.001), marital status (p = <0.001), education (p = <0.001), physical activity (p = <0.001), Family history (p = 0.027), work environment (p = 0.026), and stress (p = 0.027) had a significant relationship with the incidence of hypertension. Meanwhile, gender (p = 0.076) and dietary patterns (p = 0.419) did not show a significant relationship.
Conclusion: It can be concluded that behavioural and environmental factors such as age, stress, education, and work conditions were significantly associated on the incidence of hypertension than genetic factors and dietary patterns. Therefore, preventive efforts through health education and improvements in the work environment are essential to reduce the risk of hypertension among private sector employees.

INTRODUCTION

Non-communicable diseases (NCDs) have emerged as the leading cause of mortality in Indonesia, presenting a critical public health challenge. The country faces a double burden as infectious diseases persist alongside a dramatic rise in NCD-related morbidity and mortality. The mortality rate attributed to NCDs has increased substantially from 41.7% in 1995 to 59.5% in 2007, with cardiovascular diseases, particularly stroke and hypertension, accounting for

approximately 15.4% and 15.2% of total deaths, respectively. Hypertension, often referred to as the "silent killer" due to its asymptomatic nature, has become a major risk factor for heart disease, kidney failure, and stroke across both urban and rural populations in Indonesia (Oktamianti P, Kusuma D, Amir V, Tjandrarini DH, Paramita A. 2022).

The prevalence of hypertension in Indonesia has reached alarming levels, with national data from the 2023 Indonesian Health Survey (SKI) indicating a prevalence rate of 30.8% among the population aged 15 years and above. This represents a significant public health concern, particularly in provinces such as Central Kalimantan (38.7%), South Kalimantan (34.1%), and East Java (32.8%). In North Sumatra specifically, Medan City has documented substantial hypertension cases, with P2P NCD data from the Medan City Health Office (2023) recording 45,124 cases citywide, ranking it as the second most prevalent disease with 65,904 cases in 2022. Data from the 2023 Indonesian Health Survey (SKI) reveals a critical public health challenge characterized by a significant discrepancy between measured hypertension prevalence and formal medical diagnoses across various occupational sectors. According to the SKI 2023 technical guidelines, the category of 'Private Sector Employees' (Pegawai Swasta) encompasses private university lecturers and administrative staff, while 'Entrepreneurs' (Wiraswasta) includes informal traders such as street vendors.

In North Sumatra, this gap is particularly pronounced among the groups studied. For instance, fishermen show a prevalence of 25.4% based on direct measurements, yet only 4.8% have been clinically diagnosed by a physician. Similarly, the entrepreneur category (including street vendors) shows a measured prevalence of 29.5% against a 7.3% diagnosis rate, and private employees (including lecturers/staff) exhibit a 22.0% measured prevalence compared to only 4.9% diagnosed. This substantial underdiagnosis suggests that hypertension remains a 'silent killer' within these workforces, where individuals often remain unaware of their high-risk status until clinical screening is performed. Therefore, aligning these national occupational categories with the specific groups in this study—fishermen, lecturers, and street vendors—is essential for understanding the unique environmental and behavioral risks they face.

Understanding hypertension prevalence and its associated risk factors among specific occupational groups is crucial for developing targeted interventions. Previous research has identified several contributing factors to hypertension across different populations in the region. Studies on fishermen in Belawan have established significant associations between age ($p=0.005$) and family history ($p<0.001$) with hypertension prevalence (Buntaa et al., 2019) . Work-related psychological stressors have also been identified as significant contributors, with research on traditional market traders demonstrating a strong relationship between work stress and hypertension ($p<0.001$) (P. Siregar et al., 2023). Age has consistently emerged as a risk factor across various occupational settings, including elementary school teachers where a significant association was found ($p<0.001$) (Tindangen et al.,2020) . The fishing community in Belawan represents a particularly high-risk group, with preliminary data from Belawan Public Health Center (2024) indicating that hypertension ranks first among fishermen's health conditions with 358 recorded cases.

Hypertension is a multifactorial condition influenced by a variety of determinants. Previous research has identified several key risk factors that can be systematically categorized into individual, behavioral, and occupational/environmental factors. Individual factors, particularly age and family history, have consistently shown strong associations with hypertension across different workforces, such as elementary school teachers and fishermen in Belawan. Behavioral factors, including physical activity and dietary habits, are also critical; however, their impact often fluctuates depending on the specific demands of the occupation. Lastly, occupational and environmental factors represent a unique set of stressors. Work-related psychological stress and poor physical work environments—characterized by high noise levels, heat, or ergonomic challenges—have been identified as significant contributors to elevated blood pressure, especially among informal traders and industrial workers. Although these factors have been studied in isolated contexts (e.g., focusing only on teachers or only on fishermen). This study, therefore, seeks to answer: What are the primary risk factors associated with hypertension among selected formal and informal occupational groups—specifically fishermen, lecturers/employees,

and street vendors—in Medan City, and how do these determinants vary across their diverse work environments?

Despite the established knowledge of hypertension risk factors across various populations, there remains a significant gap in comparative evidence examining how these determinants interact across diverse occupational sectors in Medan City. Most existing research in the region has examined individual risk factors such as age, family history, and work stress in isolated contexts—focusing only on one specific group, such as teachers or fishermen. To date, there is a lack of integrated analysis that compares the collective influence of demographic, behavioral, and occupational factors among formal and informal workers. This study addresses this gap by examining the specific risk profiles of fishermen, lecturers/employees, and street vendors, thereby providing a more nuanced understanding of occupational health disparities in an urban Indonesian setting.

This research aims to provide both theoretical and practical contributions to hypertension prevention and management among high-risk occupational groups. Theoretically, the study will expand the understanding of how occupational-specific factors interact with traditional risk factors (age, family history, education, lifestyle behaviors) in determining hypertension prevalence within unique working environments, such fishermen, street vendors, and lecturers/employees. Practically, the findings will inform the development of targeted screening programs and community-based interventions specifically designed for fishermen, street vendors, and lecturers/employees. By identifying modifiable risk factors within this population, the study will provide evidence-based recommendations for the Medan City Health Office to implement culturally appropriate and occupation-specific hypertension prevention strategies, ultimately contributing to the reduction of cardiovascular disease burden in North Sumatra and supporting Indonesia's broader efforts to address the rising tide of non-communicable diseases.

METHODS

Study Design and Setting: This analytical observational study utilized a cross-sectional design to examine factors associated with hypertension among workers in Medan City. Data collection was conducted between June and August 2025 across three distinct locations representing the selected occupations. Recruitment was carried out at specific worksites: the Belawan coastal area (fishermen), University X1 and University X2 (lecturers/staff), and various central commercial districts in Medan (street vendors). The sample size was determined based on the accessibility of the participants and the feasibility of conducting direct physiological measurements during the study period. The selection of these specific occupations was based on several criteria:

1. Occupational Diversity: To compare the sedentary work environment of the formal sector (lecturers/staff) with the high-physical-demand informal sector (fishermen and street vendors).
2. Environmental Risk: To include workers from extreme outdoor environments (fishermen in coastal Belawan) and those in controlled indoor settings.
3. Accessibility and Health Urgency: Fishermen were prioritized due to high hypertension prevalence reported in preliminary data from the Belawan Public Health Center

Population and Sampling: The study population comprised workers in the formal and informal sectors in Medan City who were at risk of hypertension. A total of 176 respondents were selected using a purposive sampling technique. These respondents were categorized into three distinct occupational groups: fishermen (n=60), lecturers/employees (n=83), and street vendors (n=33). The selection of these specific groups was strategically designed to capture a broad spectrum of occupational diversity and varying environmental risk profiles. Fishermen were recruited from the Belawan coastal area to represent an informal sector exposed to extreme physical demands and environmental stressors. Lecturers and university staff were selected as representatives of the formal sector, characterized by relatively controlled indoor environments and sedentary work patterns. Street vendors were recruited from central commercial districts in Medan to represent an urban informal group with high physical activity and moderate envi-

ronmental exposure. This comparative approach allows for a more nuanced analysis of how different work environments interact with hypertension risk factors. The sample size of 176 was determined based on the accessibility of the participants and the feasibility of conducting direct physiological measurements during the study period. Respondents were included if they were actively working and willing to participate, while those with pre-existing complications that prevented blood pressure measurement were excluded.

Operational Definitions and Measurement: Primary data were collected via structured interviews and physiological measurements. Data were collected using a pre-tested questionnaire to ensure clarity and cultural appropriateness. To ensure reproducibility, variables were operationalized as follows:

- Work-Related Stress: Measured using a 10-item perceived stress scale tailored for occupational settings. Respondents were scored based on workload, time pressure, and psychological demands. Scores were then categorized into Normal (no significant stress), Low (occasional pressure), Moderate (frequent workload-related tension), and Heavy (persistent psychological distress and burnout);
- Physical Activity: Categorized based on the intensity and duration of work-related and leisure-time physical exertion. "Heavy" activity involved strenuous labor for >30 minutes/day; "Moderate" involved regular walking or light occupational tasks; and "Low" referred to sedentary patterns;
- Work Environment: Rated through self-reports of physical conditions. Classified based on physical and psychosocial conditions. A "Poor" environment was defined by exposure to environmental stressors such as high noise levels (e.g., boat engines), extreme heat, or poor ventilation, combined with low social support. A "Good" environment was defined as a controlled indoor setting with adequate facilities;
- Dietary Habit: Evaluated using a brief food frequency assessment focusing on the consumption of high-salt and fatty foods. Responses were scored and grouped into Poor, Fair, and Good
- Family History: Defined as 'At Risk' if the respondent had at least one first-degree relative (parents or siblings) with a history of hypertension.

To ensure the validity and reliability of the instruments, the questionnaire underwent a pre-test among 20 individuals with similar characteristics to the study population, resulting in a Cronbach's alpha of [Insert Value, e.g., >0.70] for the internal consistency of the behavioral and psychological scales.

Blood Pressure Measurement Protocol: Blood pressure was measured using a calibrated digital sphygmomanometer. Respondents were required to rest in a seated position for at least 5–10 minutes before measurement. Two readings were taken for each respondent with a 2-minute interval, and the average value was recorded. Hypertension status was classified according to JNC 7 guidelines: Normal (<120/80 mmHg), Prehypertension (120–139/80–89 mmHg), and Hypertension (≥140/90 mmHg), Statistical Analysis Data were analyzed using SPSS version. Bivariate analysis was performed using the Chi-square test to identify associations between independent variables and hypertension incidence. To address potential confounding between occupational groups, a multivariable logistic regression was subsequently performed to identify independent predictors.

RESULTS

Table 1 presents the distribution of respondent characteristics across the three occupational groups. A total of 176 respondents participated, comprising fishermen (n=60), lecturers/employees (n=83), and street vendors (n=33). The data reveal strong structural confounding between occupation and several key demographic variables. Specifically, the fishermen group was characterized by an older demographic (>45 years, 86.7%), lower education levels (83.3%), and high exposure to poor work environments (41.7%). In contrast, the lecturer/employee group was predominantly younger (96.4%), highly educated (100.0%), and worked in better environments (97.6%).

The prevalence of hypertension varied significantly across the three groups, with the highest burden observed in fishermen (85.0%), followed by street vendors (66.7%), and lecturers/employees (22.9%). However, these occupational categories are characterized by distinct demographic and environmental profiles that create structural confounding.

Fishermen were predominantly older and less educated, which are both independent risk factors for hypertension, whereas the lecturer/employee group was almost exclusively younger and highly educated. To determine whether occupation itself is an independent predictor or a proxy for these demographic disparities, occupational group was included as an analytic variable in the bivariate analysis and subsequently controlled in the multivariable logistic regression. This approach allows for a more rigorous interpretation of whether the 'work environment' or 'occupational type' contributes to hypertension risk independently of age and education.

Table 1. Frequency Distribution of Respondent Characteristics

Variables	Fisherman		Lecturer		Street Vendors	
	n	%	n	%	n	%
Blood pressure						
Normal	1	1.7	32	38.6	0	00.0
Prehypertension	8	13.3	32	38.6	11	33.3
Hipertension	51	85.0	19	22.9	22	66.7
Age						
< 45 Years	8	13.3	80	96.4	16	48.5
>45 Years	52	86.7	3	3.6	17	51.5
Gender						
Male	23	38.3	28	33.7	22	66.7
Female	37	61.7	55	66.3	11	33.3
Marital Status						
Not Married	1	1.7	43	51.8	3	9.1
Married	59	98.3	40	48.2	30	90.9
Education						
Low	50	83.3	0	00.0	12	36.4
High	10	16.7	83	100.0	21	63.6
Family History						
No Risk	37	61.7	28	33.7	24	72.7
At risk	23	38.3	55	66.3	9	27.3
Physical Activity						
Low	4	6.7	16	19.3	2	6.1
Moderate	3	5.0	9	10.8	2	6.1
Heavy	53	88.3	58	69.9	29	87.9
Stress						
Normal	5	8.3	21	25.3	6	18.2
Low	10	16.7	19	22.9	16	48.5
Moderate	43	71.1	29	34.9	9	27.3
Heavy	2	3.3	14	16.9	2	6.1
Work Environment						
Poor	25	41.7	2	2.4	0	00.0
Good	35	58.3	81	97.6	33	100.0
Dietary Habit						
Poor	35	58.3	37	44.6	11	33.3
Fair	20	33.3	30	36.1	14	42.4
Good	5	8.3	16	19.3	8	24.2

Table 2. Factors Affecting The Risk of Hypertension Among Workers

Variables	Blood Pressure						p-value
	Normal		Prehypertension		Hypertension		
	n	%	n	%	n	%	
Age							
< 45 Years	31	29.8	40	38.5	33	31.7	<0.001
>45 Years	2	2.8	11	15.3	59	81.9	
Gender							
Male	81	11.0	22	30.1	43	58.9	0.076
Female	25	24.3	29	28.2	49	47.6	
Marital Status							
Not Married	19	40.4	19	40.4	9	19.1	<0.001
Married	14	10.9	32	24.8	83	64.3	
Education							
Low	1	1.6	10	16.1	51	82.3	<0.001
High	32	28.1	41	36.0	41	36.0	
Family History							
No Risk	10	11.2	26	29.2	53	59.6	0.027
At risk	23	26.4	25	28.7	39	44.8	
Physical Activity							
Low	14	53.8	7	26.9	5	19.2	<0.001
Moderate	14	15.1	29	31.2	50	53.8	
Heavy	5	8.8	15	16.5	37	64.9	
Stress							
Normal	4	12.5	16	50.0	12	37.5	
Low	11	24.4	9	20.0	25	55.6	0.027
Moderate	14	17.3	18	22.2	49	60.5	
Heavy	4	22.2	8	44.4	6	33.3	
Work Environment							
Poor	1	4.0	5	20.0	19	76.0	0.026
Good	32	21.2	46	30.5	73	48.3	
Dietary Habit							
Poor	15	17.6	24	28.2	46	54.1	0.419
Fair	11	16.7	23	34.8	32	48.5	
Good	7	28.0	4	16.0	14	56.0	

The associations between various risk factors and hypertension status are summarized in Table 2. To ensure clarity in interpretation, all percentages reported in this table represent row percentages, reflecting the distribution of blood pressure categories within each risk factor level. The bivariate analysis using the Chi-square test identified several variables with a statistically significant association with hypertension (p<0.05). Age showed a strong relationship (p=<0.001), with a substantially higher prevalence of hypertension among respondents aged >45 years (81.9%) compared to those <45 years (31.7%). Significant associations were also found for marital status (p=<0.001) and low education levels (p=<0.001), where married individuals and those with limited formal education exhibited a higher burden of the disease.

Regarding behavioral and environmental factors, heavy physical activity (p=<0.001), moderate-to-heavy work stress (p=0.027), and poor work environments (p=0.026) were all significantly associated with elevated blood pressure. Notably, family history was confirmed as a significant factor in this bivariate model (p=0.027), with 44.8% of those in the 'at-risk' category being hypertensive. In contrast, gender (p=0.076) and dietary habits (p=0.419) did not reach statistical significance in this sample. These crude associations provide the basis for the subsequent multivariable analysis to control for overlapping demographic influences.

Table 3. Multivariable Logistic Regression Analysis of Factors Associated with Hypertension (n=176)

Variables	p-value	AOR	95% CI	
			Lower	Upper
Occupational Group				
Fisherman (vs. Street Vendor (ref))	0.035	3.545	0.785	16.011
Lecturer/Employee (vs. Street Vendor (ref))		0.340	0.100	1.156
Age				
<45 Years	0.280	0.526	0.164	1.688
>45 years (ref)				
Gender				
Male	0.462	1.350	0.606	3.008
Female (ref)				
Marital Status				
Unmarried	0.205	0.525	0.194	1.422
Married (ref)				
Education				
Low	0.848	1.132	0.320	4.006
High (ref)				
Family History				
No Risk	0.781	0.887	0.380	2.071
At Risk (ref)				
Physical Activity				
Light (vs. Heavy (ref))	0.747	1.017	0.315	3.277
Moderate (vs. Heavy (ref))		0.575	0.137	2.407
Stress Level				
Normal (vs. Heavy (ref))	0.935	0.892	0.202	3.934
Light (vs. Heavy (ref))		1.294	0.327	5.119
Moderate (vs. Heavy (ref))		1.166	0.313	4.334
Work Environment				
Poor	0.288	0.459	0.109	1.929
Good (ref)				
Constant	0.427	—		

To identify the independent predictors of hypertension and address potential structural confounding among the variables, a multivariable binary logistic regression analysis was performed using the Enter method. All variables that showed significant or near-significant associations in the bivariate analysis—including occupational group, age, gender, marital status, education level, family history, physical activity, stress levels, and work environment—were entered into the model.

Model Fit and Predictive Accuracy The multivariable model demonstrated a robust fit to the data, as indicated by the Hosmer and Lemeshow test (p=0.996), which suggests no significant difference between observed and predicted values. The Nagelkerke R-squared value was 0.426, implying that the included predictors explain approximately 42.6% of the variance in hypertension incidence among the respondents. Furthermore, the model achieved an overall predictive accuracy of 77.8%.

Independent Predictors As shown in Table 3, after adjusting for all other factors, occupational group emerged as the only significant independent predictor of hypertension status (p=0.035). Specifically, while the association for individual categories did not reach significance at the 0.05 level, fishermen exhibited a substantially higher likelihood of hypertension compared to street vendors (AOR = 3.545; 95% CI: 0.785 – 16.011). In contrast, lecturers and employees showed a lower likelihood of being hypertensive compared to the reference group (AOR = 0.340; 95% CI: 0.100 – 1.156).

Addressing Structural Confounding Notably, variables that were highly significant in the bivariate analysis—such as age (p=0.280), education (p=0.848), and physical activity (p=0.747)—

did not retain their statistical significance in the multivariable model. This shift indicates the presence of structural confounding, where the observed effects of age and education in the bivariate stage were likely proxies for the broader risks inherent to specific occupational categories. These results suggest that occupational environment and its associated lifestyle demands are the primary drivers of hypertension risk in this study population.

DISCUSSION

Age was significantly associated with hypertension in the bivariate analysis ($p<0.001$), with a higher prevalence of hypertension observed among older respondents. This finding is consistent with the physiological changes associated with aging, particularly increased arterial stiffness and reduced vascular elasticity, which may contribute to elevated blood pressure (Yunus et al., 2021). Similar findings have been reported by Khasanah (2022) and Hidayah et al. (2022), who also identified significant associations between increasing age and hypertension. Collectively, these findings indicate that older adults may have greater susceptibility to hypertension and therefore represent an important population for targeted screening and preventive interventions. However, given the cross-sectional design of the present study, the observed relationship should be interpreted as an association rather than a causal effect.

Evidence from international studies further supports the association between age and hypertension. Zhang and Moran (2017), in their study on trends in hypertension prevalence, awareness, treatment, and control among young adults in the United States, reported that hypertension becomes increasingly prevalent with advancing age, particularly among older populations. Similarly, Qi SF et al,. (2016), in a 22-year cohort study using data from the China Health and Nutrition Survey, demonstrated a significant relationship between age and the incidence of hypertension subtypes. These findings strengthen the biological plausibility of the present results and suggest that age remains an important consideration in hypertension prevention. Nevertheless, in the current study, age was unevenly distributed across occupational groups, particularly among fishermen, and therefore its association with hypertension should also be interpreted in relation to potential occupational and demographic confounding.

The results demonstrated a significant association between age and hypertension ($p=<0.001$), which is consistent with the physiological stiffening of blood vessels during the aging process. However, this finding should be interpreted with caution. In this study, the older demographic (>45 years) was predominantly concentrated in the fishermen group (86.7%), while the lecturer/employee group was almost entirely younger. Therefore, it is difficult to determine whether age is an independent risk factor or if it reflects the cumulative environmental stressors faced by the fishing community over time.

Researchers assume that at the age of >45 years associated with hypertension incidence can occur because the body has begun to experience natural changes, arterial elasticity begins to decrease, unhealthy habits such as a diet high in salt, lack of movement or little physical activity so that it becomes more susceptible to other non-communicable diseases, such as heart disease, stroke, hypertension and diabetes mellitus. Meanwhile, at the age of <45 years, an increase in blood pressure (hypertension) can occur due to genetic factors passed down by parents who have a history of hypertension in children and a poor lifestyle, such as smoking habits, consuming alcohol/certain drugs, foods high in salt, and fast food.

Therefore, efforts that can be made as a preventive measure are to provide health education from a young age so that people have awareness to live a healthy lifestyle as early as possible. This education includes understanding the importance of maintaining nutritional intake, regularly doing physical activities, and managing stress well. In addition, it is necessary to carry out periodic blood pressure checks, especially in individuals over 45 years old, as a form of early detection. Thus, the risk of hypertension can be minimized, and the potential for serious complications such as stroke or heart disease can be prevented more effectively.

The analysis showed no statistically significant association between gender and the incidence of hypertension (p=0.076). Although the prevalence was descriptively higher in men (58.9%) than in women (47.6%), the difference did not reach statistical significance in this

population. This suggests that the risk of hypertension in this study is relatively balanced between sexes and is likely more influenced by shared occupational and lifestyle factors rather than biological sex alone. While some literature, such as Yunus et al. (2021), notes that gender-specific risks can emerge due to hormonal changes or behavioral habits, our findings indicate that in the context of these specific occupational groups in Medan, gender is not a primary independent determinant of hypertension status.

The results of the analysis of the Marital Status variable showed a significant association with hypertension incidence (p = <0.001), where married respondents had a higher proportion of hypertension than unmarried respondents. Marital status showed a significant association with hypertension (p=<0.001), with married individuals exhibiting a higher prevalence. While this may be linked to increased psychological burdens and family responsibilities, this variable is also heavily intertwined with occupation; 98.3% of fishermen were married compared to only 48.2% of lecturers.

According to the study by Pramitasari & Cahyati (2022), which found that marital status indirectly affects health via lifestyle and stress-related behavioral mechanisms, married people tend to carry greater psychological strain from domestic obligations, economic stress, and household responsibilities, ultimately increasing their susceptibility to hypertension. These findings are in line with Purwo Setiyo Nugroho & Yonita Sari (2019) who also found a significant association between marital status and hypertension (p = 0.002). However, hypertension can still occur in both groups. In married individuals, the risk is more related to prolonged stress due to household burdens, while in unmarried individuals, the risk can come from work stress, loneliness, anxiety, and unhealthy lifestyles such as irregular diet, lack of physical activity, and smoking habits.

A long-term study by Schultz et al. (2017) demonstrated a statistically significant association ($p < 0.05$) between marital status and hypertension, revealing that unmarried individuals face a higher risk of developing the condition compared to married individuals. These findings are in line with research conducted by Son et al. (2022), which found that the low-income and married group had a significant relationship (OR 1.76; CI 1.01-3.08) with hypertension. Despite these significant associations, researchers note that hypertension can affect both married and unmarried populations, as each group is subject to distinct underlying risk factors.

The results of the statistical test showed that educational level was found to be significantly associated with hypertension incidence (p = <0.001). Respondents with low education had a higher proportion of hypertension than those with higher education, suggesting that the lower a person's education, the higher the risk of developing hypertension. The significant relationship between education level and hypertension (p=<0.001) suggests that lower health literacy may limit awareness of healthy lifestyles. Nevertheless, because low education was exclusively found among the informal sector workers (fishermen and street vendors) in this sample, education level may also serve as a proxy for the socioeconomic and occupational disparities between the formal and informal sectors. Without an adjusted multivariable analysis, these demographic factors cannot be confirmed as independent predictors in this specific population.

These findings are in line with research by Moonti et al.(2023) who found that low education increased the risk of hypertension, even in research (Moonti et al., 2023) It is stated that the risk is 2,188 times greater. Purwo Setiyo Nugroho & Yonita Sari (2019) Also reported similar results. The level of education affects a person's knowledge and awareness of a healthy lifestyle, which plays an important role in the prevention of hypertension. Poorly educated individuals tend to have limited health information and are more prone to doing strenuous physical work, while highly educated individuals, despite having good health knowledge, may be busy and have unhealthy lifestyles, such as staying up late, not exercising, or excessive caffeine consumption can increase the risk of hypertension.

Research by Sun et al. (2022) established a significant correlation between educational attainment and hypertension risk, showing that individuals with an elementary school education face a notably higher risk (p = 0.001). This aligns with findings by Zacher (2023), who reported that individuals with a high school education carry a significantly higher hypertension risk (p = 0.005) than those holding a diploma or bachelor's degree. Together, these studies confirm that

lower education levels increase hypertension risk due to barriers in health literacy, poorer lifestyle decision-making, and lower adherence to medical treatments and routine checkups.

Researchers assume that a person who is highly educated does not guarantee maintaining one's health due to a lack of self-awareness in maintaining a healthy lifestyle. On the other hand, a person with a low level of education tends to have limited health information. Therefore, the relationship between education and hypertension is not only determined by the level of formal education, but is also influenced by lifestyle, type of work, stress, and the individual's ability to implement healthy living behaviors.

The results of this study identified a significant association between family history and the incidence of hypertension (p=0.027). This finding is consistent with the established understanding that genetic factors contribute to an individual's susceptibility to hypertension. Respondents with a family history of the disease were found to be in the 'at-risk' category, representing 44.8% of the hypertensive cases in this sample. This result aligns with previous research on fishermen in Belawan, which also established a significant link between hereditary factors and elevated blood pressure.

While genetic predisposition plays a role, the presence of hypertension in individuals without a family history (59.6%) suggests that behavioral and environmental factors remain dominant drivers in this specific population. The interaction between a genetic 'trigger' and high-stress work environments or poor dietary habits may accelerate the onset of the disease. Therefore, while family history is a significant non-modifiable risk factor, preventive interventions should still prioritize modifiable factors such as stress management and work environment improvements to mitigate the overall risk. This is consistent with studies by Buntaa et al. (2019), which also found significant genetic links in fishing communities. Genetic factors contribute to a person's susceptibility to hypertension.

The bivariate analysis revealed a significant association between physical activity and hypertension (p=<0.001), with a higher prevalence of hypertension observed among respondents engaging in heavy physical activity (64.9%) compared to those with moderate (53.8%) or low activity (19.2%). While some literature suggests that strenuous activity without adequate rest may contribute to elevated blood pressure, this finding must be interpreted with caution due to occupational confounding. In this study, heavy physical activity was disproportionately represented among fishermen (88.3%) and street vendors (87.9%), groups that also faced older age and challenging work environments. Consequently, the observed association may reflect the cumulative impact of strenuous occupational labor and environmental stressors rather than physical exertion alone. This contrasts with recreational moderate-intensity physical activity, such as walking or cycling, which is generally associated with blood pressure stability.

Therefore, future research using adjusted multivariable models is necessary to disentangle the independent effects of occupational physical demands from other work-related risk factors. This indicates that too strenuous physical activity, if not balanced with enough rest and a healthy lifestyle, can actually trigger an increase in blood pressure. These findings are in line with research by Marleni (2020) Each of which reported a significant relationship between physical activity and blood pressure (p = 0.005). Adding that physical activity plays a role in controlling weight, reducing stress, and balancing the body's hormones, all of which contribute to normal blood pressure. Although physical activity is beneficial in lowering the risk of hypertension, its effectiveness is greatly influenced by the intensity, duration, and accompanying lifestyle (Ramdhika et al., 2023).

Therefore, it is recommended to regularly engage in moderate-intensity physical activity, such as walking, cycling, or light gymnastics, as they are safer and more effective in maintaining blood pressure stability. These findings are in line with findings by Cleven et al. (2020), which state that physical activity can significantly reduce the risk of hypertension in the long term. In addition, Monfared et al.,(2024) also reported that physical activity had a significant influence on reducing the risk of hypertension, with a p-value = 0.001. Both journals support that physical activity-based interventions can effectively lower blood pressure, especially if done regularly, according to the body's capacity, and accompanied by other healthy lifestyles.

Researchers assume that physical activity is known to have benefits in lowering the risk of

hypertension, but the effect is highly dependent on the intensity, duration, and lifestyle that accompanies it. Activities that are too light may be less effective in maintaining blood pressure. Therefore, the steps that can be taken are to encourage people to do regular moderate-intensity physical activity, such as walking, cycling, or light gymnastics, which have been proven to be safer and more effective in maintaining blood pressure stability.

The results showed stress levels were significantly associated with hypertension incidence (p = 0.027), with the highest proportion of hypertension in respondents with moderate stress (60.5%) and severe stress (44.4%). These findings indicate that the higher the stress level, the greater the risk of hypertension. Research by Adam et al.,(2021) and Situmorang (2020) also reported similar relationships, while Putri et al. (2023) explain that stress can increase blood pressure through vasoconstriction of blood vessels, and if it persists, can trigger permanent hypertension. Unmanaged emotional stress triggers increased sympathetic nerve activity and the release of stress hormones such as cortisol; regular blood pressure checks are important steps to prevent hypertension in individuals with moderate to high levels of stress.

Research by Balint et al. (2021) demonstrated a significant relationship between stress and hypertension risk, noting that hypertensive patients exhibit heightened stress reactivity (p=0.005), which directly links emotional stress to elevated blood pressure. This aligns with findings by Gasperin et al. (2009), who reported that high stress levels are significantly associated with blood pressure increases (p=0.001). Together, these studies confirm that psychological stress—particularly chronic or unmanaged stress—elevates the risk of hypertension in both healthy individuals and patients under medical treatment.

Researchers assume that stress plays a role in the increase in blood pressure, especially if it takes place continuously and is not properly managed. For workers, stress occurs due to too heavy workloads given by companies or superiors to employees, and erratic working hours that cause their lifestyle to be unhealthy. Therefore, efforts that can be made are to provide education about stress management, such as relaxation techniques, light exercise, and create a more supportive work or social environment. Regular blood pressure checks are also important for individuals with high stress levels, so that hypertension can be detected and controlled early.

The study found a significant association between the work environment and the incidence of hypertension (p=0.026), where respondents in 'poor' environments showed a higher prevalence (76.0%) compared to those in 'good' environments (48.3%). Physical stressors common in the fishing industry—such as chronic noise from boat engines, extreme heat, and high humidity—are plausible triggers for physiological stress that can lead to elevated blood pressure. However, this finding must be interpreted with caution due to significant occupational clustering. In this sample, the 'poor' work environment was almost exclusively reported by the fishermen group, while lecturers and street vendors predominantly reported 'good' environments. As noted by the reviewers, this creates a situation where the work environment variable may act as a proxy for the broader occupational risks of being a fisherman.

While environmental improvements such as better ventilation or noise reduction are essential, the lack of adjustment in this bivariate analysis means that the 'work environment' cannot yet be confirmed as an independent predictor separate from the overall lifestyle and demographic profile of the occupational groups.

Rahmanti and Prihatini (2021) highlighted that the work environment serves as an external factor influencing individual mindsets, lifestyles, and behaviors, which ultimately impacts overall health. Similarly, Adhiliani (2019) identified a significant association between workplace social support, quality of life, and the incidence of hypertension.

Research shows that the work environment—particularly high noise exposure—has a significant association with hypertension risk (p = 0.001), as continuous occupational noise induces physiological and psychological stress that elevates blood pressure (Irma & Handayani, 2024). These findings align with a study by Adjobimey et al. (2024), which similarly identified a statistically significant relationship between occupational environment conditions and the incidence of hypertension (p = 0.002).

The analysis indicated no significant association between dietary habits and hypertension incidence (p=0.419), a finding that aligns with some previous studies. However, this result must

be interpreted with significant caution. As highlighted by the reviewers, the dietary assessment in this study was conducted using a broad and non-validated classification (poor, fair, and good), which lacks the precision of standardized clinical dietary tools.

This lack of measurement precision likely failed to capture critical nutritional details, such as daily sodium intake levels or the frequency of processed food consumption, which are known drivers of blood pressure. Therefore, the non-significant result in this study should not be seen as proof that diet is irrelevant in this population, but rather as a reflection of the limitations in measurement precision. Future research should utilize validated food frequency questionnaires or 24-hour dietary recalls to more accurately assess the nutritional determinants of hypertension among these workers.

These findings align with research by Purwo Setiyo Nugroho and Yonita Sari (2019) as well as Harun (2019), both of which reported no significant association between diet and hypertension. This suggests that dietary intake was not the primary factor driving hypertension incidence within the population. Although an unbalanced diet theoretically increases hypertension risk, its real-world effects are often masked by confounding factors such as age, stress levels, and physical activity.

Furthermore, measurement limitations—such as unrecorded sodium or processed food intake among individuals reporting a "good" diet, or protective behaviors like exercise and abstaining from smoking among those with a "poor" diet—further complicate this link. In line with this, a meta-analysis by Cui-Jiang Wang (2016) revealed that dietary variables lacked a statistically significant relationship with hypertension ($p > 0.05$). Similarly, research by Study (2016) demonstrated that neither traditional dietary habits nor fast-food consumption showed a significant correlation with hypertension risk. Collectively, these findings underscore that the connection between diet and blood pressure is complex and multifactorial, heavily influenced by genetics, physical activity, stress, alcohol consumption, and overall lifestyle dynamics.

Study Limitations

This study has several limitations that should be acknowledged to ensure a balanced interpretation of the findings. First, the cross-sectional design precludes the determination of causal relationships between the risk factors and hypertension; the results only indicate statistical associations at a specific point in time. Second, the use of purposive sampling and the relatively small sample size (n=176) focused on three specific occupational groups in Medan City may limit the generalizability (external validity) of the findings to the broader workforce.

A significant analytical limitation is the reliance on bivariate chi-square tests in the initial analysis, which does not allow for the separation of independent effects from interrelated variables such as age, education, and occupation. This results in structural confounding, as certain occupational groups (e.g., fishermen) were inherently older and less educated. Furthermore, some variables like dietary habits and stress were measured using relatively crude, non-validated instruments, which may have lacked the precision required to detect subtle associations. Lastly, although standardized procedures were followed, the lack of a detailed reporting protocol for blood pressure measurements in the initial draft may affect the reproducibility of the study.

The inclusion of a multivariable logistic regression analysis provides a more rigorous understanding of the factors associated with hypertension among workers in Medan. While the initial bivariate analysis suggested multiple significant factors, the adjusted model reveals that occupational group is the only primary independent predictor of hypertension status ($p=0.035$).

The Role of Occupational Groups and Independent Risk, the multivariable findings confirm that the risk of hypertension is not distributed equally across the studied occupations. Fishermen exhibited a substantially higher likelihood of being hypertensive compared to street vendors (AOR = 3.545; 95% CI: 0.785 – 16.011). This suggests that the high prevalence of hypertension among fishermen (85.0%) is not merely a result of individual demographic traits but is likely driven by a “package of risks” inherent to the fishing occupation. These risks include chronic exposure to extreme work environments (noise, heat, and humidity) and high levels of psychosocial stress associated with erratic working hours and physical labor.

Addressing Structural Confounding: Age, Education, and Physical Activity A critical insight

from the multivariable model is the loss of statistical significance for variables such as age (p=0.280), education (p=0.848), and physical activity (p=0.747), despite their high significance in the bivariate stage (p=<0.001). This phenomenon confirms the presence of structural confounding noted by the reviewers.

In this sample, the older demographic and those with low education were almost exclusively concentrated in the fishermen group. Therefore, the association between age or education and hypertension in the bivariate analysis likely served as a proxy for the cumulative occupational and socioeconomic disparities between the formal (lecturers) and informal (fishermen) sectors. This highlights that while aging processes naturally increase blood vessel stiffness, the occupational environment in which one ages plays a more dominant role in determining the actual onset of hypertension in this specific population.

Family History and Multifactorial Nature: Regarding family history, although it was significant in the bivariate analysis (p=0.027), it did not remain an independent predictor in the multivariable model (p=0.781). This indicates that in this cohort, environmental and behavioral stressors associated with occupation outweigh genetic predisposition. This finding supports the theory that while genetic factors contribute to individual susceptibility, the interaction with a high-stress work environment acts as the primary "trigger" for elevated blood pressure.

Gender and Dietary Habits: Consistent with the bivariate findings, both gender (p=0.462) and dietary habits (p=0.935) showed no significant independent association with hypertension in the multivariable model. The lack of significance for diet may reflect measurement limitations, as the crude categorization (poor, fair, good) likely failed to capture precise sodium intake or frequency of processed food consumption. Similarly, the balanced risk between genders suggests that occupational exposure and shared lifestyle habits are more influential than biological sex alone in this particular workforce.

Clinical and Practical Implications

These findings underscore the need for occupation-specific interventions. Since the occupational group is the strongest predictor, preventive efforts should target not only individual behaviors but also the physical and psychosocial conditions of the work environment. For high-risk groups like fishermen, regular on-site blood pressure screening and culturally appropriate stress management programs are essential to address the significant underdiagnosis and high prevalence observed.

CONCLUSION

This study investigated the determinants of hypertension across three distinct formal and informal occupational groups (fishermen, street vendors, and lecturers/employees) in Medan City. While preliminary bivariate analysis revealed statistically significant associations between hypertension and age ($p < 0.001$), marital status ($p < 0.001$), education level ($p < 0.001$), physical activity ($p < 0.001$), stress ($p = 0.027$), family history ($p = 0.027$), and work environment ($p = 0.026$), these crude relationships were heavily confounded by baseline demographic disparities. After adjusting for overlapping covariates using multivariable logistic regression (Nagelkerke R-squared = 0.426; predictive accuracy = 77.8%, occupational group emerged as the sole primary independent predictor of hypertension status ($p = 0.035$). The burden of hypertension was disproportionately concentrated in the informal sector, with the highest prevalence observed among fishermen (85.0%), followed by street vendors (66.7%), and lecturers/employees (22.9%).

Specifically, fishermen exhibited more than three times the likelihood of hypertension compared to street vendors (AOR = 3.545; 95% CI: 0.785–16.011), whereas lecturers/employees showed lower odds of hypertension (AOR = 0.340; 95% CI: 0.100–1.156). Crucially, variables that were highly significant in the bivariate stage, including age ($p = 0.280$), education ($p = 0.848$), physical activity ($p = 0.747$), and family history ($p = 0.781$), lost statistical significance in the multivariable model. This transition confirms the presence of structural confounding, demonstrating that demographic traits and physical labor demands do not act as isolated drivers, but rather serve as proxies for the cumulative risk package inherent to specific work environments.

Gender (p = 0.462) and dietary habits (p = 0.935) showed no independent association, with the null dietary finding largely attributed to measurement imprecision in the unvalidated assessment tool.

Based on these empirical findings and noted study limitations, actionable recommendations are proposed across public health practice, policy, and future research: Occupation-Specific Public Health Interventions; Integrated On-Site Screenings & Stress Management; on-site blood pressure screening programs and Workplace Environmental & Ergonomic Improvements.

To address the empirical and methodological limitations of this study, future research should proceed along two primary avenues. First, subsequent investigations ought to incorporate precise nutritional measurement tools such as validated Food Frequency Questionnaires (FFQ) or 24-hour dietary recalls to accurately evaluate daily sodium intake and specific dietary risk factors. Second, to overcome the inherent constraints of a cross-sectional framework and a non-randomized, purposive sample (n=176), future studies should employ prospective longitudinal cohort designs with larger, randomly selected samples across broader occupational sectors to establish direct causal relationships.

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