Jurnal Epidemiologi Kesehatan Komunitas
11 (4), 2026, 338-354

JEKK

Hypertension Risk Among Rotating Shift Manufacturing Workers: Lifestyle Analysis and Intervention Booklet Development

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Article Information : Received 20 August 2026 ; Last Revised 11 October 2026 ; Accepted 18 October 2026 ; Available Online 01 November 2026 ; Published 01 November 2026

ABSTRACT

Background: Rotating-shift manufacturing workers experience heightened vulnerability due to circadian disruption and unhealthy lifestyles. Although hypertension prevalence in South Kalimantan, Indonesia, exceeds the national average, workplace preventive interventions tailored for shift workers remain scarce. This study aimed to identify lifestyle factors associated with hypertension among rotating-shift manufacturing workers and to develop an educational pocket book as a promotive-preventive intervention.
Methods: This two-phase study comprised a cross-sectional survey of 123 rotating-shift workers, analyzing lifestyle variables and blood pressure using logistic regression. Phase 2 developed a hypertension pocket book using a simplified ADDIE model and conducted a formative evaluation of its acceptability and perceived usability among 55 workers who had read it.
Result: Hypertension prevalence was 39.0%. Multivariate analysis identified high-risk coffee consumption (OR=16.046; 95% CI: 3.157-81.555), stress (OR=11.131; 95% CI: 2.591-47.823), and tobacco smoke exposure (OR=7.674; 95% CI: 2.331-25.263) as the primary factors associated with hypertension ($p<0.001$), explaining 54.9% of the variance. Notably, the wide confidence intervals for these odds ratios warrant cautious interpretation given the cross-sectional design. The developed pocket book achieved a 98.2% positive perception rate, with 100% finding it comprehensible and 89.1% intending to apply its guidelines.
Conclusion: Coffee consumption, occupational stress, and tobacco smoke exposure are the primary factors strongly associated with hypertension among rotating-shift workers. The educational pocket book demonstrated high acceptability. Companies should integrate this medium into occupational health programs, supported by continuous mentoring and policies facilitating healthy lifestyle adoption.

Keywords: Hypertension ; Manufacturing workers ; Rotating shifts; Lifestyle ; Associated factors ; Educational media.

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DOI : https://doi.org/10.14710/jekk.v11i4.34276

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Introduction

Non-communicable diseases (NCDs) account for 74% of global mortality, with hypertension being a primary contributor responsible for nearly 11 million deaths annually, predominantly from cardiovascular complications.[1-2] Longitudinal evidence indicates that even minor reductions in sleep duration can significantly elevate hypertension risk in adulthood.[3] Indonesia faces a double burden of disease, where the prevalence of hypertension exceeds the national average, particularly in South Kalimantan (44.13%).[4-5] Despite provincial multisectional strategies focusing on prevention and community-based education,[6] workplace preventive interventions for industrial workers, especially those in rotating shift systems, remain limited and are not systematically integrated into Occupational Health and Safety (OHS) programs.

Manufacturing workers constitute a vulnerable group at high risk of developing hypertension due to occupational exposures such as unhealthy lifestyles, shift work systems, and limited control over work demands. The International Labour Organization (ILO) identifies occupational stress as a collective challenge that significantly contributes to cardiovascular disorders.[7] Furthermore, WHO-ILO estimations state that night shift work accounts for 13% of the global burden of ischemic heart disease, with hypertension serving as the primary mediator in this pathophysiological pathway.[8] Extensive international epidemiological studies have confirmed the strong association between shift work and hypertension. For instance, surveys among manufacturing workers in China and South Korea reported significantly higher hypertension prevalence and increased odds among shift workers.[9-10] These empirical findings demonstrate that rotating shift work is strongly associated with the incidence of hypertension across diverse populations, underscoring that work schedules misaligned with circadian rhythms are critical determinants of workers' cardiovascular health.

This vulnerability is further exacerbated by unhealthy lifestyle behaviors stemming from circadian misalignment, including sleep deprivation, high caffeine and tobacco consumption, and reduced physical activity.[11-12] Shift workers with multiple lifestyle risk factors exhibit a substantially higher prevalence of hypertension compared to those without such factors.[13] Disrupted sleep patterns constitute a primary pathophysiological pathway linking shift work to hypertension, with both short and long sleep durations following a J-shaped curve regarding cardiovascular risk.[14-16] Poor sleep quality further accelerates blood pressure dysregulation in populations exposed to chronic occupational stress.[16] Moreover, the cumulative effect of long-term shift work exposure significantly amplifies broader cardiometabolic risks. A large-scale prospective study demonstrated that prolonged night shift work (≥5 years) markedly increases the risk of incident type 2 diabetes and related metabolic dysregulations,[17] highlighting the profound physiological toll of chronic circadian disruption. Consequently, the combined effects of shift work and unhealthy lifestyles are additive, increasing hypertension risk by up to 2.62-fold and emphasizing the critical need for comprehensive lifestyle modification interventions.[18]

Although various observational studies have confirmed the association between shift work and hypertension, the majority remain limited to identifying statistical correlations and lack the formulation of practical workplace interventions. In Indonesia, specific studies integrating lifestyle risk factor analysis with the development of contextual educational interventions for rotating shift workers remain highly limited. A substantial gap exists between epidemiological research findings and the implementation of promotive-preventive OHS programs at the corporate level, often compounded by low health literacy among workers. The novelty of this study lies in its integration of an analytical approach with needs-based development. Rather than merely identifying correlations, it explores under-researched lifestyle variables to design evidence-based solutions relevant to the realities of the workers.

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To bridge the gap between research and implementation, an OHS intervention booklet represents a potential educational medium due to its concise, visual format and ease of access. Based on the aforementioned background, this study aims to evaluate lifestyle factors associated with hypertension among rotating shift manufacturing workers and to develop an intervention booklet as a promotive-preventive educational medium that can be independently utilized by both the company and the workers.

Methods

A. Study Design

This study employed a two-phase design comprising an analytical cross-sectional study (Phase 1) and Research and Development (R&D) (Phase 2). Phase 1 aimed to identify lifestyle factors associated with hypertension, while Phase 2 focused on the development and formative evaluation of an educational intervention booklet based on Phase 1 findings. The study was conducted at a manufacturing company operating a rotating-shift system in South Kalimantan, Indonesia.

1. Phase 1: Descriptive-Analytical Cross-Sectional Study

a. Participants and Sampling

The target population comprised all 178 rotating shift workers at the partner company. Given the finite and fully accessible population size (N = 178), the sample size was determined using Slovin's formula with a 5% margin of error ($n = N / [1 + Ne^2] = 178 / [1 + 178 \times 0.05^2] = 123.18$, rounded to 123 respondents). This formula was deemed methodologically appropriate for studies involving a finite population where complete enumeration is impractical but high representativeness is required. To ensure the methodological robustness of the sample for multivariate analysis, a post-hoc verification was conducted using the *Events Per Variable* (EPV) rule for binary logistic regression. With 48 hypertension events (outcome) and six independent variables initially considered, the EPV ratio was 48/6 = 8, approaching the widely accepted threshold of 10 events per variable recommended for stable regression coefficients. This dual justification confirms that the sample size is adequate both for population representation and for multivariate modeling.

Simple random sampling based on the employee roster was employed to ensure equal probability of selection and minimize selection bias. Inclusion criteria were active rotating shift workers willing to participate. Exclusion criteria included workers on extended leave, those with a history of secondary hypertension or severe chronic diseases, and respondents with incomplete data.

B. Operational Definitions and Instruments

Data were collected using structured questionnaires and clinical measurements administered by trained research assistants.

a. Hypertension (Dependent Variable): Defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medication. Blood pressure was measured using a validated digital sphygmomanometer (Omron HEM-7120) after a minimum of 5 minutes of seated rest in a quiet environment. Two consecutive measurements were taken 1-2 minutes apart on the same arm, and the average of both readings was recorded as the final value.

b. Independent Variables (Lifestyle Factors):
   1) Coffee Consumption: "High risk" was defined as consuming >3 cups/day or consuming coffee within 4 hours of bedtime, based on WHO and Indonesian Ministry of Health guidelines.
   2) Tobacco Smoke Exposure: "High risk" included active smokers or those exposed to secondhand smoke (SHS) for >15 hours/week.
   3) Sleep Pattern: Evaluated using the validated Indonesian version of the Pittsburgh Sleep Quality Index (PSQI) A global score >5 indicated poor sleep quality ("high risk").
   4) Stress Level: Measured using the validated Indonesian version of the Perceived Stress Scale (PSS-10), with scores categorized into "low risk" (0-13) and "high risk" (14-40)

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5) Physical Activity: Assessed using the International Physical Activity Questionnaire (IPAQ). "High risk" was defined as <150 minutes of moderate-intensity activity per week.
6) Alcohol Consumption: "High risk" defined as >14 standard drinks/week for men.
7) Work Tenure: Categorized as "<5 years" or "≥5 years."

C. Confounders

Age and work tenure were identified as potential confounders, with work tenure explicitly included in the initial multivariate model to control for cumulative shift exposure. Gender was excluded since the study population was entirely male (100%). Body Mass Index (BMI) was not measured due to operational constraints. Nevertheless, incorporating work tenure alongside comprehensive lifestyle assessments provided robust control for the primary confounding pathways relevant to this specific population.

D. Statistical Analysis

Data were analyzed using SPSS version 26. Univariate analysis described frequency distributions. Bivariate analysis used chi-square tests to examine associations between independent variables and hypertension. Variables with $p<0.25$, plus confounder work tenure, entered multivariate binary logistic regression via Forward Stepwise Likelihood Ratio to identify associated factors and control confounding. Statistical significance was $p<0.05$. Model adequacy and explanatory power were evaluated using Hosmer-Lemeshow and Nagelkerke R-squared.

E. Ethical Approval and Informed Consent

This study received ethical approval from the Research Ethics Committee of Universitas Muhammadiyah Banjarmasin (Ethics Approval No. 221/UMB/KE/V/2026). Written informed consent was obtained from all participants prior to data collection, ensuring confidentiality and the right to withdraw at any time. The study was conducted in accordance with applicable regulations.

2. Phase 2: Intervention Booklet Development (Simplified ADDIE R&D Model)

Phase 2 involved developing and evaluating a health education booklet using a simplified ADDIE R&D model. Sampling 55 respondents via Slovin's formula (10% margin of error), this formative evaluation assessed user perceptions of usability, benefits, and applicability, rather than testing clinical effectiveness or causal relationships.

Result

A. Phase 1: Descriptive-Analytical Cross-Sectional Study

1. Univariate Analysis Results

Univariate analysis was conducted to describe the frequency and percentage distribution of all studied variables, encompassing the dependent variable (blood pressure status) and independent variables (demographic characteristics, occupational factors, and lifestyle behaviors). This analysis provides a baseline profile of the 123 manufacturing workers operating under a rotating shift system.

Table 1. Univariate Analysis

Variables	Frequency (n)	Percentage (%)
Blood Pressure Status		
Normal	75	61
Hypertension	48	39
Age Group (Years)		
18-29	45	36.6
30-39	49	39.8
≥ 40	29	23.6
Gender		
Male	123	100
Work Tenure		
< 5 Years	30	24.4
≥ 5 Years	93	75.6
Coffee Consumption		
Low Risk	101	82.1
High Risk	22	17.9

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Continuation of Table 1. Univariate Analysis

Variables	Frequency (n)	Percentage (%)
Tobacco Smoke Exposure		
Low Risk	49	39.8
High Risk	74	60.2
Sleep Pattern		
Low Risk	37	30.1
High Risk	86	69.9
Physical Activity		
Low Risk	102	82.9
High Risk	21	17.1
Alcohol Consumption		
Low Risk	116	94.3
High Risk	7	5.7
Stress Level		
Low Risk	101	82.1
High Risk	22	17.9

Source: Primary Data, June 2026

As presented in Table 1, 61% (n=75) had normal blood pressure while 39% (n=48) were identified with hypertension. All respondents were male (100%; n=123), predominantly aged 30-39 years (39.8%; n=49), followed by 18-29 years (36.6%; n=45) and ≥40 years (23.6%; n=29). Work tenure was mostly ≥5 years (75.6%; n=93) versus <5 years (24.4%; n=30).

Lifestyle variables revealed distinct patterns: coffee consumption was predominantly low-risk (82.1%; n=101) versus high-risk (17.9%; n=22). Tobacco smoke exposure was mostly high-risk (60.2%; n=74) compared to low-risk (39.8%; n=49). Sleep patterns were largely high-risk (69.9%; n=86) versus low-risk (30.1%; n=37). Physical activity was mostly low-risk (82.9%; n=102) with only 17.1% (n=21) high-risk. Alcohol consumption was predominantly low-risk (94.3%; n=116) with merely 5.7% (n=7) high-risk. Stress levels mirrored coffee consumption, with 82.1% (n=101) low-risk and 17.9% (n=22) high-risk.

2. Bivariate Analysis

Bivariate analysis was performed to examine the associations between lifestyle risk factors and blood pressure status using the *chi-square* test.

Table 2. Bivariate Analysis Results

No	Variables	Blood Pressure Status				p-value
		Normal		Hypertension		
		n	%	n	%	
1	**Coffee Consumption**					
	Low Risk	73	72.3	28	27.7	0.001
	High Risk	2	9.1	20	90.9	
2	**Tobacco Smoke Exposure**					
	Low Risk	43	87.8	6	12.2	0.001
	High Risk	32	43.2	42	56.8	
3	**Sleep Pattern**					
	Low Risk	28	75.7	9	24.3	0.028
	High Risk	47	54.7	39	45.3	
4	**Physical Activity**					
	Low Risk	62	60.8	40	39.2	0.924
	High Risk	13	61.9	8	38.1	
5	**Alcohol Consumption**					
	Low Risk	70	60.3	46	39.7	0.704
	High Risk	5	71.4	2	28.6	
6	**Stress Level**					
	Low Risk	72	71.3	29	28.7	0.001

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No	Variables	Blood Pressure Status				p-value
		Normal		Hypertension		
		n	%	n	%	
	High Risk	3	13.6	19	86.4	
7	**Work Tenure**					
	< 5 Years	23	76.7	7	23.3	0.043
	≥ 5 Years	52	55.9	41	44.1	

Source: Primary Data, June 2026

As presented in Table 2, chi-square tests revealed significant associations between blood pressure status and four lifestyle variables ($p<0.05$): coffee consumption, tobacco smoke exposure, sleep patterns, and stress levels, alongside work tenure ($p=0.043$). Physical activity ($p=0.924$) and alcohol consumption ($p=0.704$) showed no significant associations.

Coffee consumption demonstrated the strongest association ($p=0.001$), with high-risk consumers showing substantially higher hypertension prevalence (90.9%; n=20) compared to low-risk consumers (27.7%; n=28). Similarly, tobacco smoke exposure was strongly associated ($p=0.001$); high-risk workers exhibited 56.8% prevalence (n=42) versus 12.2% (n=6) in the low-risk group. Stress levels showed the highest magnitude of association ($p=0.001$), with high-risk workers demonstrating 86.4% prevalence (n=19) compared to 28.7% (n=29) among low-risk workers. Sleep patterns were also significantly associated ($p=0.028$), with high-risk workers exhibiting 45.3% prevalence (n=39) versus 24.3% (n=9) in the low-risk group.

Regarding occupational characteristics, workers with ≥5 years tenure showed higher hypertension prevalence (44.1%; n=41) than those with <5 years (23.3%; n=7). This suggests prolonged rotating shift exposure is associated with elevated blood pressure, consistent with the cumulative physiological impact of chronic circadian disruption.

3. Multivariate Analysis

Multivariate analysis used binary logistic regression (Forward Stepwise Likelihood Rati0) to identify lifestyle factors associated with hypertension status, acknowledging the cross-sectional design precludes causal inference. Initial variables included coffee consumption, tobacco exposure, sleep patterns, stress, and work tenure.

The stepwise selection yielded a final three-variable model (coffee, stress, tobacco) that was statistically significant ($\chi^2 = 63.914$; $p<0.001$) with good fit (Hosmer-Lemeshow $p = 0.834$). The model explained 54.9% of the variance in hypertension status (Nagelkerke $R^2 = 0.549$).

Overall classification accuracy was 79.7%, but asymmetric: the model accurately identified normal blood pressure in 93.3% of cases, yet sensitivity for detecting hypertension was considerably lower at 58.3%. This indicates the model is more effective at ruling out hypertension than identifying it. Crucially, this accuracy assessment relies solely on the training dataset without internal or external validation. Therefore, the model's generalizability remains unproven, and results should be interpreted descriptively rather than as evidence of robust predictive capability.

The statistical parameters of the final binary logistic regression model are presented in Table 3.

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Table 3. Binary Logistic Regression Results

Variables	Coefficient (B)	Odds Ratio (OR)	95% CI for OR	*p-value*
Coffee Consumption (High Risk vs. Low Risk)	2,775	16,046	3,157-81,555	0,001
Stress Level (High Risk vs. Low Risk)	2,410	11,131	2,591-47,823	0,001
Tobacco Smoke Exposure (High Risk vs. Low Risk)	2,038	7,674	2,331-25,263	0,001

Source: Primary Data, June 2026

As presented in Table 3, high-risk coffee consumption was associated with an adjusted OR of 16.046 (p=0.001; 95% CI: 3.157-81.555), indicating workers had 16.046 times the odds of being classified as hypertensive compared to low-risk consumers. Similarly, high-risk stress levels (OR=11.131; p=0.001; 95% CI: 2.591-47.823) and tobacco smoke exposure (OR=7.674; p=0.001; 95% CI: 2.331-25.263) indicated 11.131 and 7.674 times the odds of being classified as hypertensive, respectively.

Notably, the confidence intervals for all three odds ratios are notably wide, particularly for coffee consumption. This imprecision likely reflects the relatively small sample size and limited number of workers in high-risk exposure categories. Therefore, while these OR values indicate strong statistical associations, they should be interpreted with caution regarding effect magnitude, necessitating larger studies for stable estimates.

Based on the "Variables not in the Equation" table, sleep patterns (p=0.159) and work tenure (p=0.091) were excluded from the final model, as their independent contributions were no longer statistically significant after adjusting for the three retained variables.

The exclusion of sleep patterns warrants theoretical interpretation. Although sleep disruption demonstrated significant bivariate association (p=0.028), its statistical effect was absorbed by coffee and stress in the multivariate model. This aligns with a distal-proximal mediation framework: in rotating shift workers, sleep disruption acts as a distal factor triggered by circadian misalignment, which subsequently provokes proximal compensatory behaviors like increased coffee consumption and elevated psychological stress. Once these proximal mediators are accounted for, sleep's independent statistical contribution becomes insignificant. Importantly, this statistical exclusion does not diminish the clinical relevance of sleep regulation, which remains a core component of the developed intervention booklet.

B. Phase 2 Results: Intervention Booklet Development (Simplified ADDIE R&D Model)

1. Analyze Phase

The analyze phase was grounded in Phase 1 findings. The population was entirely male, predominantly aged 18-39 years (76.4%) with work tenure ≥5 years (75.6%). Approximately 39% had hypertension. Multivariate analysis identified coffee consumption (OR=16.046), stress levels (OR=11.131), and tobacco smoke exposure (OR=7.674) as primary factors associated with hypertension (p=0.001). Sleep patterns were retained due to significant bivariate association (p=0.028) and high prevalence (69.9%).

Based on these findings, the booklet focused on four primary domains: coffee consumption regulation, stress management, tobacco smoke exposure reduction, and healthy sleep pattern implementation. Physical activity and alcohol consumption were positioned as supplementary content, as they did not demonstrate significant associations (p>0.05) and most workers exhibited favorable profiles.

2. Design Phase

The booklet was structured around six topics aligned with Phase 1 findings: (1) introduction to hypertension, (2) health challenges of rotating shift systems, (3) hazards of tobacco smoke exposure, (4) healthy sleep strategies, (5) safe coffee consumption, and (6)

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stress management and self-blood pressure monitoring.

The media employed an infographic approach combining concise text, illustrations, icons, and simple layouts to facilitate comprehension. The language was communicative and instructional, avoiding complex medical terminology. Technical terms such as "circadian rhythm" and "vasoconstriction" were simplified to "the body's biological clock" and "narrowing of blood vessels," ensuring accessibility for workers with diverse educational backgrounds.

3. Develop Phase

Booklet production involved collaboration among the research team, health promotion experts, and graphic designers. Content emphasized practical information on coffee consumption regulation, stress management, sleep hygiene, and self-blood pressure monitoring. The material was visualized in infographic format with simple layouts ensuring readability. The product was developed in pocket-size format (maximum 40 pages) for portability, then prepared for feasibility validation.

4. Implement Phase

Practical feasibility was ensured through Focus Group Discussion (FGD) involving the research team and partner company's OHS Team to assess content alignment with workers' needs. Discussion outcomes guided product revision focusing on comprehensibility and relevance. Upon feasibility confirmation, the booklet was finalized and distributed to rotating shift workers as an educational intervention medium.

5. Evaluate Phase

The evaluate phase constituted a formative assessment of acceptability and perceived usability, not clinical or behavioral effectiveness. A perception questionnaire measured three aspects: ease of understanding, perceived usefulness, and self-reported likelihood of applying healthy lifestyle guidelines. This phase assessed workers' perceptions and intentions, not actual behavioral changes or clinical outcomes. Conducted 1-2 weeks post-distribution, the intervention was deemed acceptable if ≥80% of workers provided positive responses.

Table 4. Workers' Perceptions of the Hypertension Intervention Booklet

Variables	Frequency (n)	Percentage (%)
Comprehensibility		
Good	55	100
Fair	0	0
Poor	0	0
Perceived Usefulness		
Good	54	98.2
Fair	1	1.8
Poor	0	0
Applicability		
Good	49	89.1
Fair	6	10.9
Poor	0	0
Overall Perception		
Good	54	98.2
Fair	1	1.8
Poor	0	0

Source: Primary Data, June 2026

The evaluation involving 55 workers revealed that 98.2% reported positive perceptions, fulfilling the predetermined success indicator. Regarding specific dimensions, all workers (100%) rated the material as highly comprehensible, 98.2% perceived the medium as highly useful, and 89.1% indicated high likelihood of applying the guidelines. These findings demonstrate that the booklet achieved excellent acceptability as a hypertension educational medium for rotating shift workers.

Discussion

A. Prevalence of Hypertension and Characteristics of Rotating Shift Workers

This study revealed a 39.0% (n=48) hypertension prevalence among rotating shift workers, indicating a substantial cardiovascular burden requiring targeted occupational prevention. This aligns with

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previous research demonstrating significantly higher hypertension rates in high-risk shift exposure groups (80%) compared to low-risk groups (20.6%).[19]

These findings are consistent with other manufacturing sector studies. Notably, Romanian automotive night shift workers demonstrated elevated cardiovascular event risks compared to day workers (adjusted OR=1.74),[20] while Chinese coke oven workers showed increased incident hypertension risks associated with long-term industrial exposure.[21]

Furthermore, the demographic profile of this study's respondents entirely male and predominantly of productive age (18-39 years) closely reflects typical heavy manufacturing workforces. Within this demographic, physical job demands and non-standard work schedules constitute common occupational exposures, which collectively compound the cardiovascular vulnerabilities of productive-aged male workers in industrial settings.

B. Work Tenure and Cumulative Exposure to Rotating Shifts

The significant association between a work tenure of ≥5 years and hypertension incidence (p=0.043) suggests that long-term exposure to rotating shift work contributes to an elevated hypertension risk. This is corroborated by a study of 14,999 aluminum manufacturing workers in the United States, which showed an increased risk of hypertension with longer work tenure after adjusting for age.[22] Similarly, research involving 52,234 workers in France identified a dose-response relationship, where an increased risk of cardiovascular factors, including high blood pressure, became significantly apparent after five years of night shift work, and was higher in rotating shift workers compared to fixed shift workers.[23]

However, in the multivariate analysis, work tenure no longer showed a significant association after controlling for coffee consumption, stress, and tobacco smoke exposure. This suggests that the relationship between work tenure and hypertension in this study population is likely confounded or mediated by other factors, particularly habits and working conditions that may develop or worsen as an individual endures the rotating shift system over a prolonged period.

C. Coffee Consumption as a Primary Factor Associated with Hypertension (OR = 16.046)

The high odds ratio for coffee consumption in the final logistic regression model may be theoretically understood through the known physiological effects of caffeine on blood pressure regulation. Experimental evidence suggests that caffeine may induce short-term increases in blood pressure through the inhibition of adenosine receptors, stimulation of the sympathetic nervous system, and increased catecholamine release, which has been linked to vasoconstriction in controlled settings. However, it is important to emphasize that these mechanisms are derived from acute experimental studies and cannot be directly extrapolated to explain the cross-sectional associations observed in our population, where the temporal relationship between coffee consumption patterns and hypertension status remains undetermined.[24] However, these findings contrast with those observed in the general population. A meta-analysis of 25 observational studies, comprising 13 cross-sectional and 12 cohort studies, indicated that higher coffee consumption is actually associated with a reduced risk of hypertension in the general population.[25]

Other reviews on coffee consumption and cardiometabolic health also suggest that the blood pressure elevation caused by coffee is predominantly acute and short-term, thus not necessarily linked to the development of chronic hypertension.[26] This discrepancy can be attributed to the specific characteristics of the shift workers in this study. For shift workers, coffee consumption is likely not merely a daily habit but a coping mechanism to combat sleepiness during work caused by altered sleep patterns and circadian rhythms. This context may lead to repeated caffeine intake, particularly just before or during work hours, resulting in an exposure pattern fundamentally different from that of the general population.

Methodological Caveat on Effect Estimates: It is important to acknowledge that the odds ratio for coffee consumption (OR =

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16.046; 95% CI: 3.157-81.555) has a notably wide confidence interval, reflecting imprecision in the effect estimate. This imprecision likely stems from the relatively small number of workers in the high-risk coffee consumption category (n = 22) and the overall sample size. Therefore, while the association is statistically significant and contextually interpretable within the shift worker population, the exact magnitude of the effect should be interpreted cautiously and verified in larger studies.

D. Occupational Stress as a Primary Factor Associated with Hypertension (OR = 11.131)

The high OR value for stress levels indicates that occupational stress is a significant factor associated with hypertension among workers. This aligns with a cohort study of 1,784 workers in China that utilized hair cortisol levels as an objective biomarker of stress. The study demonstrated that increased occupational stress is associated with a higher risk of hypertension (RR = 4.20; 95% CI: 1.73-10.17), with cortisol playing a biological role in linking occupational stress to elevated blood pressure.[27]

From a physiological standpoint, chronic stress has been associated in longitudinal studies with activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system. Such activation has been linked to increased release of hormones such as epinephrine and norepinephrine, which may affect heart rate, myocardial contractility, and peripheral vascular resistance, thereby theoretically contributing to elevated blood pressure. Nevertheless, whether this pathway explains the strong cross-sectional association observed in our study where stress and hypertension were measured simultaneously remains speculative and requires longitudinal verification.[28] In workers under a rotating shift system, stress may originate from multiple conditions, such as the demands of meeting production targets and the difficulty of adapting sleep-wake patterns that continually change according to work schedules.

E. Tobacco Smoke Exposure as a Primary Factor Associated with Hypertension (OR = 7.674)

The proportion of workers experiencing high-risk tobacco smoke exposure reached 60.2%, with an OR of 7.674. These results highlight that exposure to secondhand smoke (SHS), whether originating from the work environment or from smoking colleagues, requires attention as a factor associated with hypertension. This finding is consistent with a meta-analysis of 783,798 non-smoking adults from 13 studies, which showed that SHS exposure is associated with an increased risk of hypertension. This association was found in both cross-sectional/case-control studies (effect size = 1.20; 95% CI: 1.08-1.34) and cohort studies (effect size = 1.17; 95% CI: 1.11-1.25), with a higher risk among individuals exposed at least three times a week and for ≥10 years.[29]

NHANES data analysis in the United States also demonstrated a dose-response relationship between serum cotinine levels, as an indicator of tobacco smoke exposure, and hypertension and systolic blood pressure. In the highest exposure group, the OR was 1.13 (95% CI: 1.04-1.24).[30] These findings also align with research identifying a significant correlation between smoking status and hypertension, where the correlation strength was actually higher in passive smokers (ρ = 0.736; $p<0.001$) compared to active smokers (ρ = 0.567; $p<0.001$).[31] This pattern confirms that indirect (passive) tobacco smoke exposure is as serious, and potentially even more hazardous, than direct exposure. This underscores the critical importance of educational interventions on smoking hazards as a preventive measure for hypertension; such educational activities have been shown to successfully increase understanding of smoking hazards from 28.33% to 100% post-intervention.[32]

It should be noted, however, that while these dose-response relationships have been established in longitudinal and experimental studies, the cross-sectional design of the

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present study cannot confirm whether tobacco smoke exposure preceded the development of hypertension in our participants or whether workers with hypertension may have different smoking behaviors. The observed association should therefore be interpreted as a statistical correlation requiring longitudinal confirmation.

F. Sleep Patterns: A Contributing Factor Excluded from the Final Model

High-risk sleep patterns were prevalent (69.9%) and significantly associated with hypertension in bivariate analysis (p=0.028), yet excluded from the final multivariate model. This occurred because sleep disturbances, coffee consumption, and stress form a synergistic cluster driven by circadian misalignment. After adjusting for coffee and stress, sleep's independent statistical effect was no longer significant.

Methodologically, this reflects a distal-proximal mediation framework. Sleep disruption acts as a distal factor triggering proximal compensatory behaviors namely, increased caffeine intake and elevated stress. When analyzed simultaneously, coffee and stress emerge as stronger proximal predictors, effectively mediating the pathway between sleep disruption and hypertension. This aligns with evidence suggesting behavioral coping mechanisms may exert a more direct physiological impact on blood pressure than sleep disruption alone. Thus, the model appropriately isolates the most actionable predictors.

Crucially, statistical exclusion does not imply clinical irrelevance. Sleep management was retained as a core booklet component. Its necessity is empirically supported by health promotion activities at PT X, where educating workers on sleep scheduling yielded a 68% improvement in understanding post-intervention.[33] Therefore, while the model accurately captures direct proximal drivers of blood pressure elevation, addressing the underlying distal factor sleep disruption remains clinically essential for comprehensive hypertension prevention among rotating shift workers.

G. Physical Activity and Alcohol Consumption: Non-Significant Factors in This Population

Physical activity (p=0.924) and alcohol consumption (p=0.704) did not demonstrate a significant association with blood pressure status in this study. These findings are likely attributable to the relatively homogeneous distribution of the respondents, as the vast majority of workers fell into the low-risk category, accounting for 82.9% for physical activity and 94.3% for alcohol consumption. This homogeneity resulted in restricted data variance, thereby limiting the statistical power to detect significant associations between these two factors and blood pressure status. Consequently, the findings of this study should be interpreted as a reflection of the specific characteristics of the study sample, rather than a basis for concluding that physical activity and alcohol consumption do not contribute to hypertension risk among shift workers in general.

H. Methodological Considerations on Effect Estimates

The exceptionally high odds ratios observed in this study warrant critical methodological reflection, as these values substantially exceed those typically reported in large-scale epidemiological studies. Several methodological factors may contribute to these inflated effect estimates:

1. Residual confounding: Despite adjusting for work tenure, our model could not account for several established hypertension determinants, including Body Mass Index (BMI), dietary sodium intake, family history, and current use of antihypertensive medication.
2. Small exposure group sizes: The high-risk categories for coffee consumption and stress each contained only 22 workers. Small cell sizes can produce unstable odds ratios with wide confidence intervals.
3. Dichotomization of continuous variables: Categorizing lifestyle variables into "high-risk" and "low-risk" groups may have introduced information loss and categorization bias, artificially inflating effect estimates.

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4. Potential overfitting: The initial consideration of five independent variables before stepwise selection may have introduced some degree of overfitting.
5. Selection and information biases**:** The reliance on self-reported lifestyle measures introduces the possibility of recall and social desirability biases. In light of these considerations, the high odds ratios should be interpreted not as precise estimates of causal effect, but as indicators of strong statistical associations within this specific occupational context.

I. Acceptability and Perceived Usability of the Booklet: A Formative Evaluation

It is essential to clarify at the outset that the evaluation phase of this study was strictly limited to assessing the acceptability and perceived usability of the intervention booklet. The study did not measure changes in knowledge, actual behavioral modification, or clinical blood pressure outcomes following the intervention. Therefore, the findings presented in this section should be interpreted exclusively as evidence of the booklet's potential as an acceptable educational medium, and not as evidence of its effectiveness in reducing hypertension risk or modifying health behaviors. Acceptability and perceived usability are necessary but insufficient conditions for intervention success; they represent the formative foundation upon which future efficacy trials can be built, but they do not constitute proof of effectiveness.

The high positive perception rate (98.2%) indicates that the booklet was exceptionally well-received by workers as an educational medium; however, this finding should not be interpreted as evidence that the booklet has been proven effective in reducing hypertension risk or modifying health behaviors. Acceptability and usability are necessary but insufficient conditions for intervention success. True effectiveness can only be established through longitudinal or experimental designs that objectively measure behavioral adherence (e.g., changes in coffee consumption patterns, stress management practices, or tobacco exposure reduction) and clinical outcomes (e.g., pre- and post-intervention blood pressure measurements). The present study's evaluation phase serves as a formative foundation demonstrating that the booklet is a viable and acceptable medium upon which future efficacy trials can be built.

Positive perception of the booklet reached 98.2%, indicating that the educational medium was exceptionally well-accepted by the workers. The highest rating was observed in the comprehensibility aspect (100.0%), followed by perceived usefulness (98.2%). These results align with existing literature on the use of booklets as health education media. A review of 10 studies utilizing booklets for hypertension education demonstrated knowledge improvement across various age groups, including adults, adolescents, and the elderly. The use of simple language combined with visual elements was identified as a key factor in enhancing readability and material comprehension.[34] Similarly, a study on a water safety booklet in Malaysia showed improvements in knowledge and attitudes following the intervention, although changes in practical or behavioral aspects did not always yield significant results.[35] A similar pattern was observed in the present study, where the domain of applicability of healthy lifestyle guidelines (89.1%) was recorded lower than the domains of comprehension and perceived usefulness. The effectiveness of face-to-face education as a well-accepted approach in worker populations is also evidenced by blood pressure screening and education activities at PT Dharma Lautan Utama in Banjarmasin, which successfully identified 31.03% previously undetected hypertension cases while simultaneously raising awareness of the importance of routine blood pressure checks.[36] This mirrors the present findings, where the perception of the applicability of healthy lifestyles (89.1%) remained lower than the ratings for comprehensibility and perceived usefulness of the booklet.

The discrepancy between the perception of the booklet's comprehensibility and usefulness versus the likelihood of applying

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healthy behaviors indicates the presence of an intention-behavior gap a condition where knowledge and the intention to engage in healthy behaviors are not fully translated into actual actions. Health promotion literature explains that while intention is a direct predictor of behavior, its translation into daily life is also constrained by environmental and structural factors beyond individual control.[37] Other research on the relationship between knowledge and health behavior also indicates that knowledge enhancement alone does not necessarily result in sustained behavioral change. Additional factors, such as self-efficacy and workplace support, significantly influence the success of behavioral modification.[38]

In the context of this study, this condition can be linked to sleep pattern management among rotating shift workers. Although workers possessed adequate knowledge and positive intentions, their sleep duration could not be entirely self-regulated due to the constraints of company-mandated work schedules. Therefore, while the booklet serves as an effective medium for enhancing knowledge and fostering positive attitudes, its optimal application requires supportive workplace environments, such as robust OHS policies, health-supportive work scheduling, and continuous mentoring. Through such integrated support, the established knowledge and intentions can be more effectively translated into healthy behaviors within daily work activities.

In summary, the evaluation findings demonstrate that the booklet was exceptionally well-received by workers in terms of comprehensibility, perceived usefulness, and self-reported intention to apply the guidelines. However, these perceptual outcomes should not be conflated with actual behavioral change or clinical improvement. The intention-behavior gap observed in our findings where applicability ratings (89.1%) were lower than comprehension (100%) and perceived usefulness (98.2%) underscores the complexity of translating health education into sustained behavioral modification. Future research must employ longitudinal or experimental designs with objective outcome measures (e.g., pre-and post-intervention blood pressure measurements, biochemical verification of lifestyle changes, and long-term behavioral follow-up) to determine whether the booklet's high acceptability translates into meaningful health improvements among rotating shift workers.

This study has several important limitations. First, the cross-sectional design precludes any inference regarding temporal precedence or causal direction. Second, residual confounding from unmeasured variables (e.g., BMI, dietary sodium intake, family history, medication use) may have influenced the results. Third, the reliance on self-reported measures introduces the potential for recall and social desirability biases. Fourth, the exceptionally high odds ratios with wide confidence intervals suggest statistical instability, likely due to the relatively small sample size and small number of workers in high-risk exposure categories. Fifth, the study population consisted exclusively of male rotating shift workers in a single manufacturing company, limiting generalizability. Sixth, the intervention booklet evaluation was strictly limited to a formative assessment of acceptability and perceived usability; its effectiveness in reducing hypertension risk remains unproven. Future studies should employ longitudinal or randomized controlled designs with comprehensive measurement of potential confounders, objective biomarkers, and rigorous evaluation of intervention effectiveness.

Conclusion

Hypertension prevalence among rotating shift workers was substantial (39.0%), with coffee consumption, occupational stress, and tobacco smoke exposure the factors most strongly associated with hypertension status in the multivariate model, explaining 54.9% of variance. Sleep patterns, although statistically excluded due to mediation effects, remain clinically relevant given their high prevalence (69.9%). The educational booklet demonstrated exceptional acceptability and perceived usability (98.2% positive perception); however, this strictly formative

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evaluation measured perceptions, not behavioral change or clinical outcomes, indicating a promising educational medium rather than proven effectiveness. These findings warrant urgent targeted occupational health interventions addressing the associated factors, with sleep regulation remaining critical. Integrating the booklet into OHS programs and implementing policies facilitating healthy lifestyles require empirical testing through longitudinal or experimental designs with objective biomarkers to establish effectiveness in modifying behavior and reducing blood pressure.

Acknowledgement

The authors wish to express their gratitude to the Directorate General of Research and Development, Ministry of Higher Education, Science, and Technology, for the financial support provided through the Novice Lecturer Research (PDP) Grant for the Fiscal Year 2026. Appreciation is also extended to the partner company and all workers for their permission, support, and active participation in this study.

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