

The effect of smoking habits on hypertension risk: A systematic review and meta-analysis

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Abstract

Background: Smoking is a major modifiable risk factor for cardiovascular diseases, including hypertension. This study aimed to synthesize recent evidence on the association between smoking and hypertension using a systematic review and meta-analysis approach. This study was conducted by researchers from the Study Program of Magister Kesehatan Masyarakat, Universitas Jambi, Jambi, Indonesia, to synthesize recent evidence regarding the association between smoking and hypertension.

Method: We conducted a systematic search of PubMed, Google Scholar, and OpenAlex to identify observational studies published between 2020 and 2025. Studies reporting odds ratios (OR) or adjusted odds ratios (AOR) for the association between smoking and hypertension among adults were included. A random-effects model was used to estimate pooled effect sizes.

Results: Ten studies were included in the meta-analysis. The pooled analysis showed that smoking was significantly associated with increased risk of hypertension (pooled OR = 1.24; 95% CI 1.19–1.30). The forest plot demonstrated variability in individual study estimates, although the pooled effect indicated an overall positive association between smoking and hypertension.

Conclusion: Smoking exposure was significantly associated with an increased risk of hypertension. Smoking prevention and cessation programs should be strengthened to reduce the burden of cardiovascular disease.

Keywords: Hypertension; Smoking Habits; Smoking Intensity; Smoking Duration.

INTRODUCTION

Hypertension continues to be a major global health challenge and represents one of the primary contributors to cardiovascular morbidity and mortality worldwide. Persistent elevation of blood pressure increases the likelihood of serious complications such as stroke, coronary artery disease, heart failure, and chronic kidney disease. Despite advances in prevention and treatment strategies, the global prevalence of hypertension remains high and continues to rise, particularly in low- and middle-income countries.

Smoking is widely recognized as a preventable behavioral risk factor that adversely affects cardiovascular health. Exposure to cigarette smoke introduces nicotine and numerous toxic compounds into the body, which may induce acute and chronic increases in blood pressure. Biological mechanisms proposed to explain this

association include stimulation of the sympathetic nervous system, impairment of endothelial function, vascular inflammation, oxidative stress, and increased arterial stiffness. Over time, these physiological changes may contribute to sustained hypertension.

Although numerous observational studies have examined the relationship between smoking and hypertension, findings remain inconsistent across populations and study designs. Differences in exposure measurement, adjustment for confounding variables, and demographic characteristics may explain variations in reported effect sizes. Therefore, synthesizing recent evidence through a systematic review and meta-analysis is essential to provide a more precise and comprehensive estimate of the association between smoking behavior and hypertension risk among adults.

This study aims to systematically evaluate and quantitatively summarize current research findings regarding the relationship between smoking exposure and the occurrence of hypertension in adult populations.

METHOD

This research employed a systematic review and meta-analysis approach conducted between September and November 2025. A comprehensive literature search was carried out using three electronic databases: PubMed, Google Scholar, and OpenAlex. The search process utilized Boolean operators combining the following keywords: ("smoking" OR "cigarette smoking" OR "active smoker") AND ("hypertension" OR "high blood pressure") AND ("risk factor" OR "odds ratio" OR "risk ratio" OR "incidence" OR "prevalence").

Study selection was performed according to PRISMA guidelines. Titles and abstracts were initially screened, followed by full-text evaluation based on predefined eligibility criteria. The methodological quality of included studies was assessed using the STROBE checklist to ensure adequate reporting standards for observational research.

Eligible studies were required to report adjusted effect estimates, particularly adjusted odds ratios (AOR) with corresponding 95% confidence intervals. Extracted data included study characteristics, sample size, exposure definition, outcome measurement, and effect estimates. Statistical synthesis was conducted using an inverse-variance random-effects model to account for between-study variability. The pooled effect size was calculated to determine the overall association between smoking exposure and hypertension risk.

INCLUSION AND EXCLUSION CRITERIA

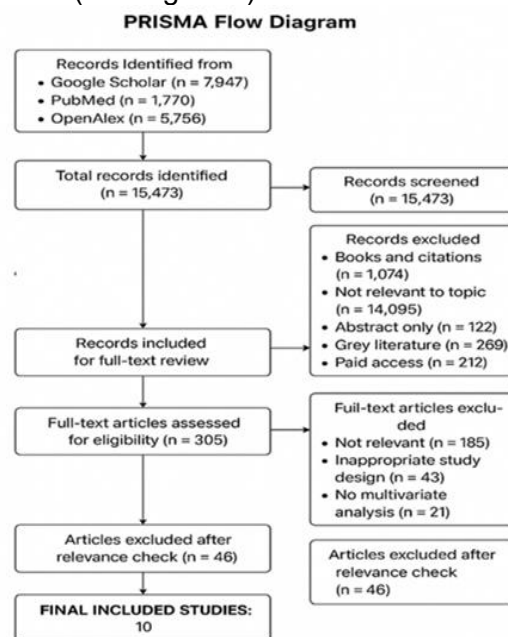
The inclusion criteria were: (1) primary research articles examining the association between smoking and hypertension; (2) outcomes related to hypertension incidence defined as clinical diagnosis or blood pressure $\geq 140/90$ mmHg; (3) independent variables

including smoking habits, number of cigarettes consumed, or duration of smoking; (4) studies involving adult populations (≥ 18 years); (5) articles published between 2020 and 2025; (6) full-text articles available in English or Indonesian; and (7) articles retrieved from Google Scholar, PubMed, and OpenAlex databases.

The exclusion criteria included: (1) studies without multivariate analysis reporting adjusted odds ratios (AOR); (2) articles requiring paid access or unavailable for download; and (3) grey literature.

RESULTS

Researchers extracted data from articles was conducted using inverse-variance random-effects models based on adjusted odds ratios reported in primary studies. In the initial search 15473 articles were obtained from (Google Scholar; 7947, Pubmed;1770 and OpenAlex;5756) (result). After checking for duplication, identification, and screening, 56 articles were filtered, of which 46 articles were excluded that were not relevant to the research criteria. the author checked the suitability of 10 articles using the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) criteria. (see Figure 1)



A total of ten studies were included in the meta-analysis. The included studies were

conducted in various countries including Indonesia, Saudi Arabia, Yemen, India, China, Korea, Peru, and the United States. Most studies used a cross-sectional design,

while two studies used a cohort design. The sample sizes ranged from 300 to 101,839 participants. Smoking exposure

Table 1. Characteristics of Included Studies

No	Author (Year)	Country	Study Design	Population	Sample Size	Exposure	Effect Size (OR/AOR)	95% CI
1	Paramita et al. (2024)	Indonesia	Cross-sectional	Adult workers	80,602	Passive smoking	2.11	1.85–2.41
2	Mohammed et al. (2025)	Saudi Arabia	Cross-sectional	Adults ≥18 years	384	Smoking status	0.18	0.07–0.48
3	Muafa et al. (2025)	Yemen	Cross-sectional	Community adults	300	Smoking behavior	1.88	1.05–3.35
4	Lal et al. (2024)	India	Cross-sectional	Adult men (NFHS-5 dataset)	101,839	Daily smoking	1.17	1.06–1.29
5	Cao et al. (2024)	China	Cohort	Adults ≥18 years	30,778	Secondhand smoke	1.15	1.02–1.29
6	Park et al. (2024)	Korea	Cross-sectional	Korean adults	3,457	Current smoking	0.98	0.81–1.19
7	Alfaqeeh et al. (2023)	Indonesia	Cross-sectional	Adult population	32,670	Smoking status	1.297	1.198–1.404
8	Gao et al. (2023)	Cohort	China	Adult population	5,625	Heavy smoking	1.50	1.05–2.16
9	Gonzales-Falcón et al. (2025)	Peru	Cross-sectional	National survey adults	29,826	Smoking behavior	0.98	0.94–1.02
10	Wu et al. (2026)	USA	Cross-sectional	NHANES adult population	28,967	Smoking status	1.18	1.10–1.27

A random-effects meta-analysis of ten observational studies was conducted to estimate the association between smoking and hypertension. The pooled analysis showed that smoking exposure was associated with an increased risk of hypertension (pooled OR = 1.24; 95% CI 1.19–1.30), included active smoking, daily smoking, heavy smoking, and passive

smoking. The reported effect sizes ranged from OR 0.18 to OR 2.11, showing variability across studies. Some studies reported increased odds of hypertension among smokers (OR >1), whereas others showed inverse or near-null associations (OR ≤1). The individual and pooled effect estimates are presented in the forest plot (Figure 2).

Figure 2. Forest Plot

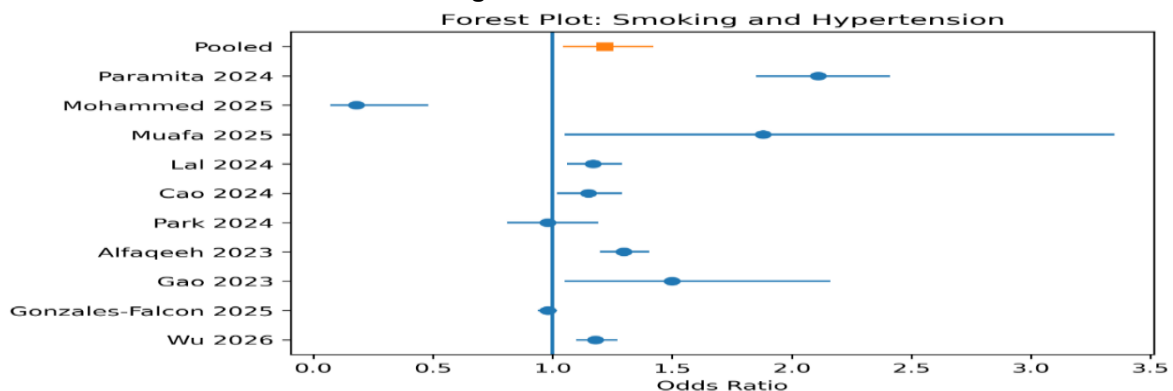
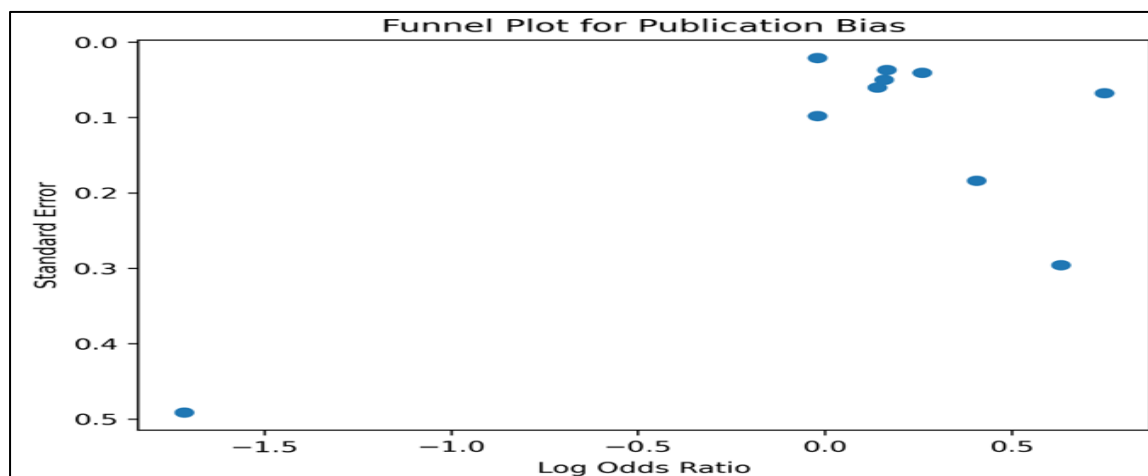


Figure 3. Funnel Plot

Publication bias was assessed using a funnel plot. Visual inspection of the funnel plot showed a relatively symmetrical distribution of studies around the pooled effect estimate, suggesting no strong evidence of publication bias.

Table 2. Risk of Bias Assessment (STROBE)

No	Author (Year)	Study Design	Sample Representativeness	Exposure Measurment	Outcome Measurement	Counfonding Control	Overall Quality
1	Paramita et.al (2024)	Cross sectional	Low risk	Low risk	Low risk	Moderate risk	Good
2	Mohammade et al (2025)	Cross sectional	Moderate risk	Low risk	Low risk	Moderate risk	Moderate
3	Muafa et al (2024)	Cross sectional	Moderate risk	Moderate risk	Low risk	Moderate risk	Moderate
4	Lal et al (2024)	Cross sectional	Low risk	Low risk	Low risk	Moderate risk	Good
5	Cao et al (2024)	Cohort	Low risk	Low risk	Low risk	Low risk	Good
6	Park et al (2024)	Cross sectional	Low risk	Low risk	Low risk	Moderate risk	Good
7	Alfaqeeh et al (2024)	Cross sectional	Low risk	Low risk	Low risk	Moderate risk	Good
8	Gao et al (2023)	Cohort	Low risk	Low risk	Low risk	Low risk	Good
9	Gonzales-Falcon et al (2025)	Cross sectional	Low risk	Low risk	Low risk	Moderate risk	Good
10	Wu et al (2026)	Cross sectional	Low risk	Low risk	Low risk	Low risk	Good

The quality assessment of the included studies using the STROBE checklist indicated that most studies had good methodological quality. Eight studies were categorized as having good quality, while two studies were rated as moderate quality due to limitations in sample representativeness and control of confounding variables.

Table 3. Summary of Evidence for Smoking and Hypertension

Exposure Domain	No. of Studies	Study Design	Population	Effect Direction	Consistency	Certainty of Evidence
Smoking status	5 studies (Indonesia, Saudi Arabia, USA, Korea, Peru)	Cross sectional	Adults	Increased risk	Mostly consistent	Moderate
Daily Smoking	1 Study (India)	Cross sectional	Adults men	Increased risk	Consistent	Moderate
Heavy Smoking	1 Study (China)	Cohort	Adults	Increased risk	Consistent	Moderate
Passive smoking	2 Studies (Indonesia, China)	Cross sectional	Adults	Increased risk	Consistent	Moderate
Smoking behavior	1 Study (Yemen)	Cross sectional	Community Adults	Increased risk	Limited evidence	Low

The synthesis of evidence from the included studies indicated that smoking exposure was generally associated with an increased risk of hypertension. Most studies reported a positive association between smoking and hypertension, although some studies showed inverse or near-null associations. Variability in effect estimates across studies suggests that differences in population characteristics and study methods may influence the observed relationship. The overall synthesis of evidence from the included studies is summarized in table Summary of Evidence for Smoking and Hypertensi.

DISCUSSION

The findings of this meta-analysis indicate that smoking is associated with a higher likelihood of hypertension among adults, with a pooled odds ratio of 1.24. This pooled estimate suggests an overall positive association between smoking exposure and hypertension, although individual studies showed variability in effect direction and magnitude. Several studies, including Mohammed et al., Park et al., and Gonzales-Falcón et al., reported inverse or near-null associations. These differences may be attributable to variations in study populations, smoking exposure measurements, sample

characteristics, confounding adjustments, and study design.

Variations in effect magnitude may reflect differences in exposure intensity, duration of smoking, and adjustment for confounding variables such as age, obesity, alcohol use, and socioeconomic status.

Previous studies have suggested a possible dose-response relationship, where greater smoking intensity and longer duration of exposure may be associated with higher hypertension risk. Findings from previous literature support the biological plausibility of the association between smoking and hypertension.

Pathophysiological explanations include chronic activation of adrenergic pathways, vascular endothelial injury, inflammation, and structural vascular remodeling, all of which contribute to sustained blood pressure elevation.

Passive smoking exposure was also identified as a potential contributor to hypertension risk. This finding emphasizes that cardiovascular harm is not limited to active smokers and highlights the importance of smoke-free environments. Additionally, emerging tobacco products may pose similar cardiovascular risks, warranting further investigation.

Nevertheless, several limitations must be acknowledged. Most included studies employed cross-sectional designs, limiting the ability to infer temporal causality. Self-reported smoking status may introduce misclassification bias. Residual confounding cannot be entirely excluded. In addition, differences in effect measures and exposure definitions across included studies may have contributed to heterogeneity in the findings. Therefore, careful interpretation of pooled estimates is necessary. Despite these limitations, the pooled evidence suggests that smoking remains an important and modifiable risk factor associated with hypertension. From a preventive perspective, integrating smoking cessation strategies into hypertension screening and cardiovascular risk management programs may significantly reduce disease burden. Future research should prioritize longitudinal studies with standardized exposure assessment and comprehensive confounder adjustment.

CONCLUSIONS

Smoking exposure was generally associated with an increased risk of hypertension among adults, although variability across individual studies was observed. Both active and passive smoking may contribute to elevated blood pressure. Strengthening tobacco control policies and smoking cessation interventions remains essential for reducing the global burden of hypertension and cardiovascular disease.

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