Asia Pacific Environmental and Occupational Health Journal (ISSN 2462 -2214), Vol 10 (1): 1-10, 2024
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ASSOCIATIONS BETWEEN INDOOR AIR POLLUTANTS AND PREHYPERTENSION ACROSS DIVERSE POPULATIONS: A SYSTEMATIC REVIEW

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ABSTRACT

Background: It is now known that indoor pollution may be a factor in unfavourable health outcomes. Prehypertension has attracted interest because it helps identify potential cardiovascular hazards in the future. The purpose of this systematic review is to summarize the research that has been done on the relationship between indoor pollution and prehypertension in various groups.

Method: A thorough search was carried out in the databases of PubMed, EBSCO, and Web of Science from 1946 to October 2021. Information about indoor pollutants, prehypertension, and outcomes were examined in articles that met the inclusion criteria. A total of 14 papers were chosen for in-depth analysis.

Result: The evaluated studies covered a range of indoor pollutants. It was shown that prolonged exposure to indoor pollution was associated with higher blood pressure, especially in vulnerable populations like children and adolescents. Notably, dietary variables proved to have an impact on this association.

Conclusion: This systematic review shows how urgent it is to put preventative measures in place to lessen the harmful cardiovascular consequences of indoor pollution. The integration of the current data points to a strong correlation between indoor pollutants and prehypertension, raising questions regarding the health of populations exposed to these pollutants.

Keywords: Indoor pollution, prehypertension, cardiovascular health, air pollutants

1. Introduction

The quality of indoor air is a critical determinant of human health and well-being, with far-reaching implications for both individual and public health(Cincinelli & Martellini, 2017). In recent decades, there has been a growing concern about the potential health risks posed by indoor air pollutants, particularly their association with cardiovascular health(Uzoigwe et al., 2013). For example, the use of smokeless coal is associated with higher degrees of IHD in the people of China(Bassig et al., 2020). Hypertension, a major global public health concern, is a significant contributor to cardiovascular disease burden(Mills et al., 2020). Prehypertension, characterized by elevated blood pressure levels that fall just below the diagnostic threshold for hypertension, represents a crucial stage for intervention and prevention efforts(Elliott & Black, 2007). The interventions can

be in the form of antihypertensives and the preventions can be changes in diet, exercise, and living in a healthy non-pollutant environment among many others (Alpsoy, 2020; Fuchs et al., 2015).

While considerable research has explored the impact of outdoor air pollution on cardiovascular health, the role of indoor air pollutants in relation to prehypertension remains an area of active investigation. It was concluded in a metanalysis that indoor air pollution from solid fuels is an important risk factor for hypertension(Li et al., 2020). Another study showed that air pollution might play a role in the early progression of cardiovascular diseases(S. Zhang et al., 2023). Environmental heavy metals and persistent organic pollutants are noteworthy in the pathogenesis of hypertension through oxidative stress, inflammatory responses, autonomic dysfunction and endocrine disruptions, as well as modification of vascular smooth muscle structure and reactivity. Obesity, insulin resistance, high serum uric acid levels, genetic factors, epigenetic modifications to DNA structure, the influence of non-coding RNAs, and histone modification and fetal programming have already been published as key contributors to hypertension. In addition to alterations in sodium homeostasis, impaired renin angiotensin, mechanisms causing renal interstitial inflammation have also been reviewed recently as potential causes of hypertension.(Lu et al.2018). However, understanding the potential link between indoor air pollutants and prehypertension is of paramount importance, as it could inform targeted interventions to mitigate the risk of hypertension development.

The existing body of knowledge primarily focuses on outdoor air pollutants and their cardiovascular effects, often overlooking the potential influence of indoor air pollutants. Indoor environments, where individuals spend a significant portion of their time, can harbor a complex mixture of pollutants arising from various sources, including combustion processes, building materials, and household activities. This systematic review aims to address this gap in the literature by comprehensively examining the associations between indoor air pollutants and prehypertension across diverse populations.

The primary objective of this systematic review is to identify and synthesize studies that have investigated the relationship between indoor air pollutants and prehypertension. This review seeks to analyze the types of indoor air pollutants that have been studied in relation to prehypertension and their respective sources and to assess the existing evidence regarding the strength and consistency of associations between indoor air pollutants and prehypertension in diverse populations, geographical regions and across different study designs.

By systematically examining the available evidence, this review aims to contribute to a comprehensive understanding of the potential role of indoor air pollutants as modifiable risk factors for prehypertension. Such insights have the potential to inform public health policies, interventions, and strategies aimed at reducing the burden of cardiovascular diseases on a global scale.

2. Materials and Method

To systematically address our research objectives, we adopted a structured approach using the Population, Intervention, Control, and Outcome (PICO) framework, which has proven effective in framing focused research questions within community settings (Aslam & Emmanuel, 2010). Our study utilized the PICO concepts to formulate a well-defined research question that illuminates the current unresolved aspects within community contexts. A succinct summary of the PICO components is presented in Table 1 for reference. The systematic literature search was conducted to identify relevant articles within a specified timeframe, from June 1st to October 11th, 2021. We employed an extensive search strategy across three prominent databases: PubMed,

EBSCO, and Web of Science (WOS). These databases were selected due to their comprehensive coverage of pertinent literature. The search encompassed articles published from as early as 1946 up to the concluding date of October 11th, 2021. This time span ensured the inclusion of a robust array of studies spanning decades.

The search process encompassed meticulous screening and selection steps, adhering to predefined inclusion and exclusion criteria. The selected studies were evaluated based on their relevance to the investigation of indoor air pollutants and their associations with prehypertension in diverse populations.

Table 1: PICO Framework

PICO	Concept
Population	Individuals spanning all age groups
Intervention	Any type of indoor air pollution
Control	-
Outcome	Pre-hypertension, Masked hypertension, and hypertension

2.1. Criteria for Inclusion and Exclusion

The criteria employed for the inclusion and exclusion of studies in this systematic review are outlined in Table 2. Due to the extensive volume of articles already present within the selected databases, literature from gray databases was not incorporated in this review. These predefined criteria were methodically applied to the selection process, ensuring a focused and rigorous approach to the identification and evaluation of relevant studies for this comprehensive systematic review.

2.2. Review Protocol

Our systematic search was conducted using a meticulous selection of keywords to ensure comprehensive coverage of relevant literature. Specifically, PubMed search incorporated both keywords and Medical Subject Headings (MeSH) terms, while EMBASE and Web of Science (WOS) were queried using keywords exclusively. Due to the substantial volume of results generated, a two-step approach was adopted. Initially, results were extracted from the databases, followed by a secondary analysis of article titles and abstracts to ascertain their relevance for inclusion or exclusion.

Table 2: Inclusion and Exclusion Criteria

Inclusion	Exclusion
Encompassed human subjects of all age groups	Studies that did not emphasize or incorporate indoor pollution
Subjects exposed to any form of indoor pollution	Studies that did not focus on Pre-hypertension, Hypertension, and associated complications
Included Pre-hypertension, Hypertension, and other pollution-related complications	-
Papers written in English	Articles in languages other than English
Full text is accessible	Full text is not accessible

For this systematic review, a comprehensive search strategy was developed using the Population, Intervention, Control, and Outcome (PICO) framework. The search aimed to identify relevant studies investigating the association between indoor pollutants and prehypertension. In the Population category, we included human subjects of all age groups. The Intervention category encompassed various forms of indoor pollution, including terms such as "Air Pollution, Indoor/adverse effects," "Tobacco Smoke Pollution/adverse effects," and related MeSH terms. Additionally, a wide range of relevant keywords were employed, such as "Indoor pollution," "pollutants," "biomass," "smoke," "carbon monoxide," and others. In the Control category, no specific terms were utilized.

Finally, the Outcome category focused on prehypertension and related terms such as “Prehypertension/epidemiology,” “Masked Hypertension/epidemiology,” and associated MeSH terms. The keywords used for outcomes encompassed “Blood pressure,”

"prehypertension," "masked hypertension," "cardiovascular disease," and "borderline hypertension." This search strategy aimed to comprehensively retrieve articles addressing the association between indoor pollutants and prehypertension, utilizing both MeSH terms and relevant keywords across different databases (Table 3).

Table 3: Search Strategy:

PICO	MeSH Terms	Keywords
P = All	-	-
I = Indoor Pollution	("Air Pollution, Indoor/adverse effects"[MeSH]) OR ("Air Pollution, Indoor/statistics and numerical data"[MeSH]) OR ("Air Pollution, Indoor/prevention and control"[MeSH]) OR ("Tobacco Smoke Pollution/adverse effects"[MeSH]) OR ("Tobacco Smoke Pollution/statistics and numerical data"[MeSH]) OR ("Tobacco Smoke Pollution/prevention and control"[MeSH])	Indoor pollution OR pollutants OR biomass OR smoke OR pollution OR carbon monoxide OR pm 2.5 OR particulate matter OR coal OR kerosene OR soot OR stove OR fuel OR charcoal OR animal dung OR wood OR cookstoves OR lead OR formaldehyde OR wood smoke OR nitrogen dioxide OR nitrogen oxide OR cooking OR fuel oils OR environmental exposure OR solid fuel combustion OR household air pollution OR tobacco smoke
C = -	-	-
O = Prehypertension	("Prehypertension/epidemiology"[MeSH]) OR ("Prehypertension/etiology"[MeSH]) OR ("Prehypertension/physiopathology"[MeSH]) OR ("Prehypertension/complications"[MeSH]) OR ("Prehypertension/diagnosis"[MeSH]) OR ("Prehypertension/etiology"[MeSH]) OR ("Masked Hypertension/epidemiology"[MeSH]) OR ("Masked Hypertension/statistics and numerical data"[MeSH]) OR ("Masked Hypertension/epidemiology"[MeSH]) OR ("Masked Hypertension/etiology"[MeSH]) OR ("Masked Hypertension/statistics and numerical data"[MeSH]) OR	Blood pressure OR prehypertension OR masked hypertension OR cardiovascular disease OR borderline hypertension

3. Results and Findings

Our initial search yielded a total of 787 studies aligned with our research objectives (PUBMED = 685, WOS = 31 and EBSCO = 40). Among these, 31 duplicates were removed, leaving 756 unique articles for evaluation. After thorough assessment, 727 articles were excluded for not meeting the rigorous criteria set for this review. A subsequent eligibility screening, performed independently by two reviewers, identified 29 articles that underwent further evaluation.

Regrettably, three articles were unattainable despite our best efforts. Consequently, a total of 14 articles were deemed eligible based on the predetermined criteria and underwent meticulous analysis by all authors. The detailed selection process is illustrated in Figure 1.

3.1. Organizing, analyzing, and summarizing reporting of data

Extracted data from the published literature was organized and summarized to provide an evidence-based narrative picture of the background, epidemiology, pathophysiology, and possible consequences of indoor pollution.

3.2. Assessment of bias across studies

A chart was created to find any risk of bias, including any reporting, article selection or risk of bias in the article selected, detection, performance, attrition and outcome reporting bias. No bias was detected in any of the articles used.

	("Masked Hypertension/diagnosis"[MeSH])	

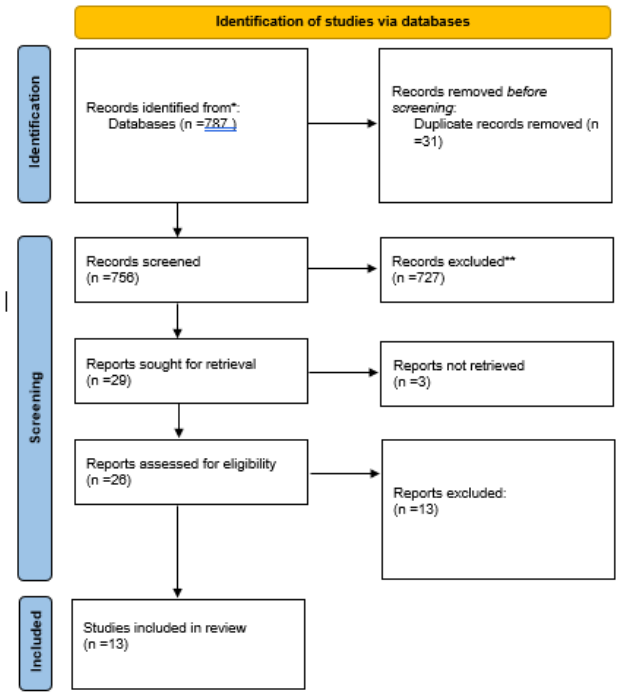

FIGURE 1: Flow chart demonstrating literature search and selection of studies

3.3. Assessment of bias across studies

A chart was created to find any risk of bias, including any reporting, article selection or risk of bias in the article selected, detection, performance, attrition and outcome reporting bias. No bias was detected in any of the articles used.

3.4. Patient and public involvement

Neither patients nor the public was directly involved in this study's planning, design, and conduction.

4. Discussion

The present systematic review aimed to comprehensively assess the association between indoor pollutants and pre-hypertension across various populations (Table 4). Our review sheds light on the diverse range of studies exploring this important relationship and provides insights into the potential impact of indoor pollution on prehypertension prevalence and related cardiovascular outcomes.

Initially, it was thought that only risk factors for both hypertension and pre-hypertension mainly included older age, high BMI, and having diabetes (Rahman et al., 2018). In young American Indians with a low burden of cardiovascular risk factors, arsenic exposure was found to be associated with increased left ventricular (LV) wall thickness and LV hypertrophy. This association was particularly pronounced in participants with prehypertension or hypertension (Zhang et al., 2019). In a study done in Iran among school-going children, it has been discovered that the prevalence of prehypertension is 7.44% among these kids while the prevalence of hypertension is 6.82%. This is an alarming discovery (Ebrahimi et al., 2015). In a study conducted in Kenya, it was observed that approximately one in every two Kenyan adults have prehypertension (Mecha et al., 2020).

Our findings highlight the significance of long-term exposure to indoor pollutants, such as particulate matter (PM2.5), sulfur dioxide (SO2), ozone (O3), and biomass cookstove emissions, in contributing to elevated blood pressure levels (Young et al., 2019). Notably, the study by (J. Zhang et al., 2020) underscores the influence of dietary factors in modifying the link between air pollution and blood pressure, especially in children (J. Zhang et al., 2020). This emphasizes the multifaceted nature of the indoor pollution-prehypertension relationship and the potential for mitigation through dietary interventions.

Furthermore, geographical variations in indoor pollution sources and exposure patterns have been observed. Studies conducted in diverse settings, including China, Iran, Honduras, and Nigeria, have revealed varying prevalence rates of prehypertension and hypertension. The study by (Amiri et al., 2007-2011)

underscores the consistent high prevalence of prehypertension and hypertension among Iranian adolescents, both in urban and rural areas, indicating a pressing need for early preventive strategies across different populations (Amiri et al., 2019).

The implications of gender and age on the indoor pollution-prehypertension relationship have also been explored. Gender-specific differences were observed in certain studies, such as the association between cigarette smoking and masked hypertension in Chinese men (D. Y. Zhang et al., 2020). Similarly, the study by (Mokgwathi et al., 2015-2016) highlighted varying prevalence rates of hypertension and prehypertension among male and female adolescents in Botswana. These gender disparities may reflect underlying biological or lifestyle factors that warrant further investigation (Mokgwathi & Mwita, 2020).

Our review also highlights the complexity of indoor pollutants' effects on cardiovascular health. While some studies suggest a direct association between biomass cookstove emissions and elevated blood pressure (Young et al., 2015), Among rural women in southern Nigeria, the utilization of biomass fuel led to elevated household levels of PM2.5. This was found to be independently associated with higher systolic blood pressure, carotid intima-media thickness (CIMT), and increased likelihood of prehypertension (Ofori, Fobil, & Odia, 2018). While others, like (Lu et al. 2018), present inconclusive findings regarding phthalate exposure and hypertension risk (Lu et al., 2018). A study conducted in Korea has shown that blood lead levels below the threshold for the harmful effects of lead were significantly associated with prehypertension (Lee et al., 2016). This underscores the need for comprehensive studies that consider the intricate interplay between different pollutants, individual susceptibility, and other risk factors. For future research, it is imperative to conduct longitudinal studies to better understand the causal relationships between indoor pollutants and pre-hypertension, considering various demographic and environmental factors. Additionally, investigations into the effectiveness of interventions, such as improved cookstove technologies or air filtration systems, in reducing indoor pollutant exposure and mitigating cardiovascular risks should be prioritized. Furthermore, exploring the potential synergistic effects of multiple indoor pollutants and their interactions with genetic predispositions can provide valuable insights into personalized prevention and management strategies for prehypertension and related cardiovascular diseases.

5. Conclusion

In conclusion, our systematic review underscores the importance of indoor pollution as a potential contributor to prehypertension across various populations. Long-term exposure to indoor pollutants, particularly in vulnerable groups such as children and adolescents, appears to be associated with increased blood pressure levels. However, further research is needed to elucidate the precise mechanisms underlying this relationship and to develop effective intervention strategies aimed at reducing indoor pollution exposure and mitigating its impact on cardiovascular health.

Acknowledgement

The authors would like to thank the Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah.

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Table 4: Results from individual Studies

Title	Author	Year	Study Type	Country	Indoor Pollution	Gender	Age	Prevalence	Key Findings
Air pollution and diet modify blood pressure in Chinese children	Zhang et al.	2017	Prospective Cohort	China	Air Pollution	M: 54%, F: 46%	6 - 12 yrs	PreHTN: 11.9%, HTN: 19.1%	PM2.5, SO2, O3 linked to child BP; diet influence observed.
Iranian adolescents: Urban-rural trends in prehypertension and hypertension	Amiri et al.	2007 - 2011	Cross-sectional	Iran	HTN/PHT Adolescents	M: -, F: -	15–19 yrs	PreHTN: Urban 2.16, Rural 1.92; HTN: Urban 2.40, Rural 1.82	Persistent pre-HTN & HTN trends across urban and rural Iranian adolescents.
Biomass cookstove pollution and BP among Honduran women	Young et al.	2015	Cross-sectional	Honduras	Biomass Cookstove	M: 0, F: 147	25 - 56 yrs	-	Traditional stoves linked to higher BP in women, age-sensitive.
Smoking, masked hypertension, and Chinese men	Zhang et al.	2009 - 2015	Cross-sectional	China	Cigarette Smoking	M: 1646, F: 0	≥ 18 yrs	Daytime masked HTN associated with smoking, especially in evenings.	Smoking tied to daytime & evening ambulatory masked HTN in men.
Phthalates and hypertension risk in adults	Lu et al.	2018	Review	USA, Sweden, China	Phthalate Exposure	M: -, F: -	1 - 80 yrs	-	Inconclusive link between phthalates and adult hypertension.
Prehypertension in Iranian school children	Ebrahimi et al.	2015	Cohort	Iran	PreHTN/Hypertension Kids	M: 53.80%, F: 46.20%	6 - 12 yrs	PreHTN: 7.44%, HTN: 6.82%	Alarming childhood pre-HTN & HTN prevalence, rural disparities.
Cardiac Geometry, Arsenic Exposure, and Young Adults	Pichler et al.	2016	Cohort	USA	Arsenic Exposure	M: 39.30%, F: 60.70%	14 - 50 yrs	LVH: 4.6%	Arsenic exposure linked to increased LV wall thickness & hypertrophy.
Burden of prehypertension in Kenyan adults	Mecha et al.	2015 - 2018	Cross-sectional	Kenya	HTN Burden	M: 34%, F: 66%	≥ 18 yrs	PreHTN: 54.5%, HTN: 20.8%	Urgent need for national BP screening among Kenyan adults.
Mercury exposure accelerates hypertension in rats	Fardin et al.	2018 - 2019	Animal Testing	Brazil	Mercury Exposure	-	4-week-old Rats	BP & heart effects due to chronic mercury exposure in rats.	

Cardiovascular risk factors in Botswana adolescents	Mokgwathi et al.	2015 - 2016	Cross-sectional	Botswana	HTN Risk Factors	M: 32.70%, F: 68.30%	Mean 17.1 yrs	PreHTN: 15.5%, HTN: 13.1%	Hypertension, obesity, and alcohol prevalent among Botswana youth.
Hypertension prevalence, patterns, and risk in Bangladesh	Rahman et al.	2009 - 2010	Cross-sectional	Bangladesh	HTN Risk Factors	M: 4312, F: 4963	≥ 25 yrs	PreHTN: Urban 39.1%, Rural 47.1%; HTN: Urban 12.8%, Rural 19.4%	High prevalence of hypertension, prehypertension, tied to age, BMI, and diabetes.
Rural Nigerian women and household biomass fuel	Ofori et al.	2018	Cross-sectional	Nigeria	Household Biomass Fuel	F: 389	≥ 18 yrs	-	Biomass fuel linked to higher systolic BP & prehypertension in rural Nigerian women.
Mercury exposure accelerates hypertension development	Simões et al.	2019	Animal Testing	Brazil	Mercury Exposure	-	4-week-old Rats	Chronic mercury exposure speeds hypertension development in rats, involving oxidative stress.	
Blood lead levels and prehypertension in Korea	Lee et al.	2007 - 2013	Cross-sectional	South Korea	Lead Exposure	-	-	-	-