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Systematic Review

Unveiling the hidden threats: second-hand and thirdhand smoke's impact on health – a systematic review

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ABSTRACT

Cigarette smoking remains a significant global public health concern, contributing substantially to morbidity and mortality worldwide. This article examines the evolving understanding of the smoking epidemic, with particular emphasis on India, the world's second-largest consumer of tobacco. Despite notable progress in tobacco control initiatives, substantial challenges persist. Exposure to secondhand smoke (SHS) and the emerging concept of thirdhand smoke (THS) present serious health risks, especially within domestic environments. Drawing on a synthesis of existing research, this paper explores perceptions of THS among the Indian population and identifies demographic factors influencing these perceptions. The findings indicate that older adults, females, individuals with higher levels of education, and non-smokers are more likely to recognize the adverse health effects associated with THS. Furthermore, the study highlights the significant public health risks posed by exposure to SHS and THS, emphasizing the heightened vulnerability of children. These findings underscore the urgent need for comprehensive smoke-free policies. The article recommends the implementation of targeted educational interventions, the strengthening of smoke-free regulations, and further research to better understand the health impacts of THS. Addressing THS alongside conventional tobacco control measures can enable policymakers and public health authorities to reduce tobacco smoke exposure and promote healthier environments for all.

Keywords: Secondhand smoke, Thirdhand smoke, Tobacco control, Public health risk, Vulnerability of children, Smoke-free policies

INTRODUCTION

Cigarette smoking is a preventable epidemic that contributes substantially to global mortality and morbidity.[1,2] A "smoking epidemic" is characterized by an initial increase in smoking prevalence, followed by a gradual decline, with a corresponding rise and subsequent fall in smoking-related diseases occurring two to three decades later.[3] According to global estimates, the number of smokers is projected to exceed 1.6 billion worldwide.[4] Tobacco use is responsible for nearly six million deaths annually. The ninth World Health Organization (WHO) Report on the Global Tobacco Epidemic indicates that although many countries have made progress in tobacco control, intensified efforts are required to protect populations from the hazards of secondhand smoke (SHS) and thirdhand smoke (THS). In the United States, exposure to SHS alone is estimated to cause approximately 41,000 deaths each year, according to the Centers for Disease Control and Prevention (CDC).[5]

India is the world's second-largest consumer of tobacco and accounts for nearly one-sixth of all tobacco-related deaths globally.[6] The tobacco epidemic in India is distinctive due to the widespread use of both smoking and

smokeless forms of tobacco. With the implementation of smoke-free legislation in public places, homes have increasingly become a major source of SHS and THS exposure, particularly among children.[7]

Data from the National Family Health Survey (NFHS-5, 2019–2021) indicate that tobacco use is more prevalent among men, rural populations, individuals with low literacy levels, economically disadvantaged groups, and other vulnerable populations.[8] Findings from the global adult tobacco survey (GATS) reveal that 28.6% of adults in India are current tobacco users, including 42.4% of men and 14.2% of women. Smokeless tobacco use is particularly common, affecting 29.6% of men and 12.8% of women, with higher prevalence observed in rural areas compared to urban settings.[9]

In 2019, SHS exposure alone accounted for an estimated 171,000 deaths and 4.3 million disability-adjusted life years (DALYs) globally.[10] GATS-2 data show that 48.8% of Indian households permit smoking indoors, including 38.2% of urban households and 54.4% of rural households. Furthermore, 35.0% of non-smokers reported exposure to SHS at home, with exposure rates of 25.0% in urban areas and 40.4% in rural areas.[9]

Although public smoking bans aim to protect public health, some evidence suggests that they may inadvertently increase smoking within domestic environments, thereby posing risks to children's health. However, studies from countries such as Ireland and the United Kingdom demonstrate similar trends, while other nations, including the United Kingdom, Canada, the United States, and Australia, have reported increases in smoke-free homes following the introduction of public smoking restrictions.[11,12] Exposure to SHS, which contains numerous toxic and carcinogenic chemicals, can be significantly reduced through the adoption of smoke-free home rules. Providing a smoke-free environment is essential to protect communities, particularly children, from the adverse effects of SHS and THS exposure.

Several factors influence the establishment of smoke-free homes, including the presence of smokers within the household, parental education levels, and awareness of the harmful effects of SHS and THS on children's health.[13] The detrimental health effects of active smoking and SHS exposure have been extensively documented and have informed smoking cessation and reduction strategies.[8,14] Active smoking has been associated with a wide range of diseases, including cancer, stroke, coronary heart disease, respiratory illnesses, diabetes, rheumatoid arthritis, and impaired immune function.[15] In contrast, limited research has examined THS, its potential health consequences, and its role in influencing preventive smoking behaviors. As THS is a relatively recent concept, further investigation is warranted.

The aim of this paper is to review awareness of THS in India, explore the lesser-known health impacts of SHS and THS, and propose implementation strategies to reduce exposure and mitigate the adverse effects of SHS and THS in both public and domestic settings.

METHODS

Study design and reporting guidelines

This study is a systematic review conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines. The review protocol was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42025643395, ensuring methodological transparency and minimizing the risk of reporting bias.

Search strategy

A comprehensive literature search was conducted to identify relevant studies examining SHS and THS and their associated health impacts. Major electronic databases, including PubMed, Scopus, and Web of Science, were systematically searched for articles published up to December 2023. In addition, Google Scholar and ResearchGate were searched to ensure broad coverage of academic and scientific literature.

The search strategy utilized a combination of controlled vocabulary and free-text terms. Key search terms included "thirdhand smoke," "secondhand smoke," "knowledge," "belief," "impact," and "public health risk." Boolean operators (AND/OR) were applied as appropriate to refine the search strategy. Furthermore, reference lists of all included studies were manually screened to identify additional relevant articles.

Study selection

The study selection process was independently conducted by two reviewers based on predefined inclusion and exclusion criteria, which were finalized a priori through mutual discussion and consultation with a third reviewer. Following the initial search, all retrieved records were imported into Microsoft Excel for data management, and duplicate articles were identified and removed. Titles and abstracts of the remaining records were independently screened by the two primary reviewers. Discrepancies in study selection were resolved through discussion. In cases where consensus could not be achieved, reasons for disagreement were documented, and the third reviewer served as an arbitrator. Full-text versions of potentially eligible studies were subsequently retrieved and independently assessed by both reviewers to determine final inclusion.

Data extraction

After completion of the eligibility assessment, data were independently extracted by two reviewers using a pre-

designed and standardized data extraction form. Extracted data included essential study elements such as study characteristics (author, year of publication, study design, and location), population characteristics, exposure details related to SHS and THS, and reported health outcomes. Any discrepancies in data extraction were resolved through discussion to ensure consistency and accuracy.

Data analysis

Due to heterogeneity in study designs, populations, outcome measures, and assessment tools related to SHS and THS, a qualitative synthesis was undertaken. Extracted data were systematically organized and summarized using descriptive methods. Comparisons were made across studies with respect to study characteristics, participant demographics, exposure settings, awareness and perceptions of SHS and THS, and reported health outcomes to identify recurring patterns, similarities, and differences.

The findings were narratively synthesized to explore associations between SHS and THS exposure and health outcomes, as well as variations in awareness and perceptions across different population groups. Where applicable, subgroup analyses were conducted based on demographic factors such as age, sex, education level, smoking status, and place of residence (urban or rural). Owing to methodological diversity, statistical meta-analysis was not performed. Instead, emphasis was placed on contextual interpretation and thematic integration of findings to provide a comprehensive understanding of the public health risks associated with SHS and THS exposure.

Risk of bias assessment

The risk of bias in the included studies was independently assessed by two reviewers using appropriate quality appraisal criteria based on study design. Observational studies were evaluated across key domains, including selection bias, measurement bias, confounding, and outcome assessment. Specific considerations included clarity of study objectives, adequacy of sample selection, validity and reliability of exposure and outcome measurements, control of confounding factors, and completeness of outcome reporting.

Disagreements in risk of bias assessments were resolved through discussion, and when necessary, consultation with the third reviewer. Studies were categorized as having low, moderate, or high risk of bias based on overall methodological quality. The findings of the risk of bias assessment were incorporated into data interpretation, with greater emphasis placed on evidence from studies assessed as having lower risk of bias. This approach facilitated a balanced and cautious synthesis of evidence regarding the health impacts of SHS and THS.

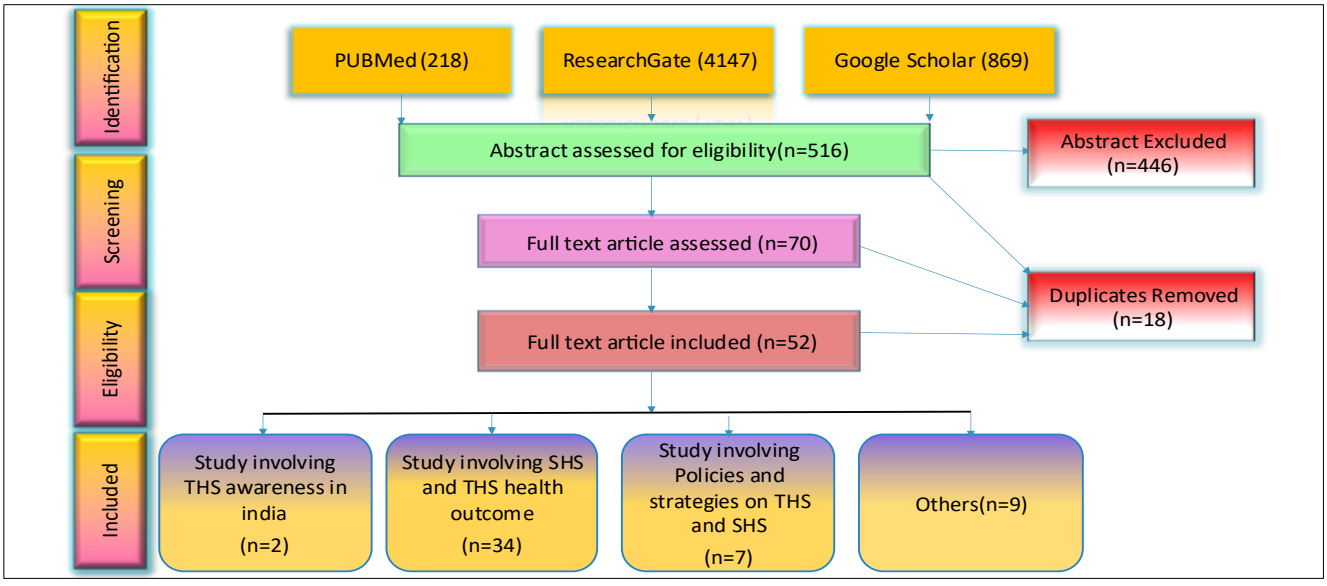

Figure 1: PRISMA flow diagram of studies.

RESULTS

Perceptions and awareness of THS among Indians: implications for tobacco control strategies

There have been only a limited number of studies on this important topic, and THS is a relatively novel concept that has not yet been thoroughly investigated. This review highlights Indians' perceptions and understanding of THS and provides support for a paradigm shift away from traditional tobacco control strategies.

Findings from a study conducted by Chandran in Bangalore revealed a significant association between the overall mean score of the beliefs about thirdhand smoke (BATHS) scale and its subscales with smoking status, age (in years), gender, and highest level of education.[16] Older individuals, females, those with higher educational

attainment, and non-smokers were more likely to strongly believe that THS has adverse health effects and that it persists in the environment. Similar findings were reported in a study conducted by Xie et al, except that younger participants scored higher on the BATHS scale and its subscales.[17] Non-smokers were more likely to believe that smoking had a negative influence on environmental persistence and health and consequently scored higher on the BATHS scale and its subscales.

These findings are consistent with a study by Roberts et al, which reported that never-smokers and current non-smokers were more likely than smokers and former smokers to believe that residual tobacco smoke has harmful effects on children's health. In addition, a study by Indumathy among smokers and non-smokers aged 15–45 years visiting a private dental college in Chennai revealed that awareness of thirdhand smoke was higher among non-smokers compared to smokers.[18] Smokers may be more responsive to THS-related concerns than non-smokers who live with smokers, as they frequently observe and complain about stains and residues on household surfaces.

Despite this, many participants had not heard of THS and were unfamiliar with the acronym. Several respondents even questioned whether residues present in dust and on surfaces could adversely affect adults and children in the household.

Mitigating the public health risks associated with SHS and THS exposure

SHS and THS have been shown to increase the risk of various health problems among non-smokers when exposed to typical ambient levels.[19] Previous scientific evidence has consistently demonstrated that exposure to SHS poses a significant public health risk.[20-22] Repeated exposure to SHS has been associated with several diseases, including asthma and pneumonia, sudden infant death syndrome, lung cancer, increased left ventricular mass, and myocardial infarction.[23-26] In addition, studies have shown that synthetic compounds present in SHS can cross the placental barrier during pregnancy and adversely affect neurodevelopment in newborns by impairing respiratory control mechanisms.[27,28]

Evidence also indicates that early-life exposure to SHS is associated with various sleep-related symptoms among children aged 6–18 years.[29,30] Exposure to SHS during early life, along with subsequent sleep disturbances, adversely affects the cardiovascular system and increases the risk of coronary heart disease and stroke in later life.[31,32] Inhalation of SHS causes cellular damage in the lungs of non-smokers. Some studies suggest that SHS exposure may increase the risk of breast cancer, nasopharyngeal cancer, and cancers of the nasal sinuses in adults; leukemia, lymphoma, and brain tumors in children; and obesity in boys during early adolescence.[33]

Previous studies have confirmed that non-smokers are at an increased risk of mortality from ischemic heart disease, lung cancer, and all causes combined due to SHS exposure.[34] While both active smoking and passive smoking are risk factors for lung cancer, the risk associated with secondhand smoke exposure is comparatively lower.[35] However, non-smokers continue to exhibit a notable incidence of lung cancer, suggesting the involvement of additional risk factors beyond active and passive smoking.[36,37] Furthermore, passive smoking has been linked to adverse mental health outcomes, including an increased risk of dementia and worsening depressive symptoms.[38,39]

Children, toddlers, and infants are particularly vulnerable to tobacco smoke exposure due to their immature respiratory and immune systems.[40] Primary exposure sources include parental smoking, ingestion of contaminated dust, dermal absorption, and inhalation of volatile components. Studies have reported elevated hand nicotine levels in children even when parents are non-smokers.[41] Nitrosamines, which are recognized carcinogenic compounds present in THS, are known to cause cancer.[42] Additionally, exposure to SHS and THS may significantly influence the occurrence, transmission, and progression of COVID-19 among vulnerable populations.[43]

This study further highlights that SHS exposure contributes to a range of health conditions, including lower respiratory tract infections in infancy and early childhood, middle ear disease requiring adenotonsillectomy, and cervical, breast, and lung cancers among non-smokers.[44] Addressing SHS exposure is therefore critical not only from a public health perspective but also for social and economic reasons, underscoring the need for active involvement of healthcare professionals and policymakers to reduce SHS exposure among non-smokers.[45]

Understanding and addressing THS exposure

Global efforts to reduce passive smoking have intensified, with smoking cessation and encouraging others to quit identified as the most effective strategies to protect against exposure to SHS and THS. Indoor smoking bans represent another highly effective public health intervention. Environmental measures such as opening windows, sitting in separate areas, improving ventilation, or using air conditioning and fans do not provide adequate protection against SHS and THS exposure.[46] The only proven method to fully eliminate the risks associated with environmental tobacco smoke is the establishment of 100% smoke-free environments.[7,47]

National and local governments can protect non-smokers from SHS and THS exposure in homes, public venues, and workplaces by implementing and enforcing evidence-based policies that eliminate smoking from public spaces.[48] Decontaminating homes and vehicles previously used by smokers can be costly due to persistent smoke

residues that stain surfaces and produce lingering odors. Remediation services for buildings affected by tobacco smoke may help reduce exposure and facilitate environmental recovery.[49] Effective removal of tobacco odors from surfaces requires the elimination of contaminated items such as carpets and furniture, along with the use of appropriate cleaning agents. Ozone generators and ammonia-based cleaning products have been suggested for removing nicotine and polycyclic aromatic hydrocarbons (PAHs) from surfaces. However, ozonation of THS-contaminated environments can generate secondary organic aerosols and increase concentrations of volatile organic compounds (VOCs), carbonyls, and particulate matter. Scientific evidence on the effectiveness and safety of these interventions remains limited, and several harmful byproducts have been identified following nicotine ozonation.[50] Further research is therefore required to evaluate the risks associated with ozone use in THS remediation, including potential byproduct formation and any therapeutic benefits.

Smoke-free policies aim to eliminate SHS exposure and thereby prevent the formation of new THS. However, existing smoke-free regulations often fail to address THS contamination and its transport into smoke-free spaces. Emerging evidence on THS supports the need to expand and strengthen indoor smoking restrictions to ensure truly smoke-free indoor environments. Recognizing THS as a distinct public health concern may help address current regulatory gaps and strengthen tobacco endgame strategies. The persistence of THS reinforces the case for comprehensive indoor smoking bans by highlighting the socioeconomic consequences of commercial tobacco use and engaging new stakeholders, including tenants, homebuyers, and environmental organizations.[51,52]

Current tobacco control policies should extend beyond active smoking to address indoor contamination that persists long after smoking has ceased, including identification, remediation, and cost-sharing mechanisms. The hazardous legacy of tobacco smoke disproportionately affects vulnerable populations such as children, older adults, and immunocompromised individuals. Socioeconomically disadvantaged populations are more likely to reside in older and substandard housing, further increasing their exposure risk. To safeguard public health, smoke-free regulations, environmental protections, and tenant rights require careful evaluation and strengthening. Moreover, manufacturers, suppliers, and retailers must assume responsibility for preventing and mitigating the long-term environmental and health impacts of their tobacco products.

DISCUSSION

This article examines the critical issue of THS and its implications for tobacco control strategies, with a particular focus on Indians' perceptions and understanding of THS. It emphasizes the need for a paradigm shift away from outdated tobacco control measures toward more comprehensive approaches that explicitly address THS exposure. The findings discussed in the article highlight the importance of demographic factors—such as age, gender, educational attainment, and smoking status—in shaping beliefs about THS. For example, older individuals, females, those with higher levels of education, and non-smokers were more likely to recognize the adverse health effects of THS and its persistence in the environment.[16-18] These insights are essential for designing targeted interventions and educational campaigns aimed at increasing awareness of THS, particularly among populations that may be less informed or less concerned about its risks.

The article further outlines the public health risks associated with both secondhand smoke (SHS) and THS exposure, underscoring the wide range of health conditions linked to tobacco smoke, including respiratory illnesses, cancers, and cardiovascular diseases.[19-26,33-35] It also highlights the heightened vulnerability of children, infants, and toddlers to tobacco smoke exposure due to their immature respiratory and immune systems, reinforcing the urgent need for protective public health measures.[40,41,44,45]

To address THS exposure, the article advocates for comprehensive smoke-free policies and practical strategies to reduce tobacco residue in indoor environments. These include environmental remediation measures such as disinfection, repair services, and the use of specialized cleaning products and ozone-based treatments to remove THS contaminants.[49,50] However, the article also acknowledges the limited scientific evidence regarding the effectiveness and potential health risks of some of these remediation methods, emphasizing the need for further research. Additionally, it calls for strengthening existing smoke-free regulations to explicitly address THS contamination and prevent its transfer into smoke-free spaces. Recognizing THS as a distinct public health concern may help close regulatory gaps and strengthen tobacco endgame initiatives.[51,52]

By highlighting the socioeconomic consequences of tobacco use and its persistent environmental legacy, the article underscores the importance of coordinated action among policymakers, public health authorities, healthcare professionals, and other stakeholders to protect vulnerable populations and promote healthier living environments.[48] Overall, the article provides valuable insights into the complexity of THS and emphasizes the necessity of multifaceted tobacco control strategies that address not only active smoking but also passive and residual tobacco smoke exposure. It reinforces the need for continued research, public awareness initiatives, and policy interventions to mitigate the public health risks associated with THS and to achieve smoke-free environments for all.

CONCLUSION

This study found that smokers perceive the health impacts of THS to be significantly less harmful than non-smokers

do. Further research is needed to determine the levels of THS-related carcinogens on household surfaces, the mechanisms through which these substances enter the human body, and their associated health consequences. Educational and policy initiatives may benefit from emphasizing THS exposure and its health effects as an additional rationale for promoting smoke-free environments. Moreover, well-designed quantitative studies examining perceptions of THS are essential to better understand this phenomenon and to evaluate the effectiveness of educational interventions aimed at increasing public awareness.

Exposure to SHS and THS represents a significant global public health concern. Although public awareness and understanding of the risks associated with THS exposure have increased over time, it remains largely overlooked in health and environmental strategies. This highlights the need for focused research on the levels of THS-related carcinogens present on domestic surfaces, their routes of human exposure, and their long-term health impacts. Despite growing awareness, THS exposure is often insufficiently addressed in public health and environmental policies. To effectively mitigate this issue, future research should prioritize the characterization of chemical constituents, long-term exposure effects, secondary by-products, toxicological profiles, and the biological mechanisms underlying THS-related health outcomes, particularly among vulnerable populations.

Such evidence is critical for enabling health policymakers to comprehensively assess the population-level health impacts of tobacco smoke exposure and to develop effective strategies to protect susceptible groups, thereby supporting public health goals in the context of a *Viksit Bharat*.

Recommendations

Smoking should be discouraged in all settings to protect children from tobacco-related health hazards; restricting smoking solely within the home is insufficient.

Targeted educational interventions are necessary to inform and persuade parents about the detrimental effects of THS on children's health.

Improved awareness of THS and its harmful effects on non-smokers, along with stricter regulations, supportive attitudes, and consideration of economic and social factors, can discourage non-smokers from initiating smoking and encourage smokers to quit.

Evidence from THS research should be more widely utilized to promote smoke-free environments. Clinicians can incorporate THS-related information into tobacco control programs and clinical practice, educating both smokers and non-smokers about the importance of smoking cessation and encouraging them to inform family members and friends.

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