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World no tobacco day
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World no tobacco day 2023

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Editorial: World no tobacco day 2023

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Editorial on the Research Topic
World no tobacco day 2023

Introduction

31 May marks World No Tobacco Day (WNTD), an annual global campaign led by the World Health Organization (WHO) to spotlight the dangers of tobacco use, expose the deceptive practices of the tobacco industry, empower people to assert their right to health and protect future generations from tobacco-related harm (1). For the year 2023, the theme for WNTD was "Grow food, not tobacco" pointing out the ways in which ensuring food security in the face of global change requires sustainable food production (2).

There is well-established evidence of the irreparable harm that tobacco causes to health (7 million deaths annually) (3), the environment (600 million trees are chopped down every year and 766,571 metric tons of cigarette butts, along with 894,700 e-cigarettes, are littered) (4) and farmers (economic hardships, labor exploitation, environmental degradation, and health problems) (5). Tobacco cultivation is resource-intensive and not only damages public health by fueling tobacco-related diseases but also leads to environmental degradation (e.g., deforestation, pesticide pollution, contaminating water sources, and soil depletion) that harms ecosystems and exacerbates climate change, thereby jeopardizing future food security (6). In the past decades, there has been a global shift in tobacco cultivation from high-income countries to low- and middle-income regions. This shift has contributed to environmental harm, including soil degradation and ecosystem disruption, driven by the heavy use of agrochemicals and deforestation for tobacco curing. These practices have also adversely affected the health of smallholder farmers, exposing them to hazardous chemicals and exacerbating food insecurity (7). Furthermore, tobacco production emits 80 million tons of carbon dioxide equivalent every year (8).

Special collection on World No Tobacco Day

The Research Topic of nine articles in the current "Frontiers of Public Health" issue focuses on the 2023 WNTD theme "Grow food, not tobacco". The contributions explored key public health and policy issues related to tobacco control, including the environmental impact of cigarette filters, exposure to secondhand smoke, the dual use of cigarettes and e-cigarettes, gender inequity and smoking patterns, public perceptions of e-cigarette regulations, compliance with tobacco vendor density laws, and industry interference in policymaking.

One article discussing the proposed ban on cellulose acetate cigarette filters in the European Union presented the key reasons for the ban, focusing on both human health and environmental impacts (Everaert et al.). It also examined the potential outcomes of such a ban and explored public opinion along with the tobacco industry's response. Two articles focused on secondhand smoke (SHS) exposure and smoke-free policies. One of these articles emphasized the need to develop targeted interventions to reduce SHS in homes and vehicles, particularly among youth belonging to racial, sexual, and gender minority groups (Talluri et al.). The tobacco industry markets smoking as a symbol of freedom and equality for women, especially younger ones, associating it with sophistication and fashion. This messaging makes women more likely to take up smoking or vaping as a form of empowerment or stress relief (9). The second article discussed factors influencing (positively and negatively) the adoption of comprehensive smoke-free policies by the local governments in cities of China (Feng et al.). The use of e-cigarettes as a replacement for smoking (displacement) or simply in addition to cigarettes (add-on use) was also explored in this Research Topic, highlighting patterns of dual use, its impact on smoking cessation, and public health implications (Kroeger et al.). The study suggests that dual use often fails to displace cigarette smoking and may undermine efforts to quit. Another article also described a two-way link between smoking and reduced quality of life, especially with regard to mental health, among teachers (Lizana et al.). Smokers were found to have significantly lower mental wellbeing scores, and those with poorer mental health were more likely to smoke. Gender-specific approaches were also found to be essential for effective tobacco prevention among youth. A time-based ecological analysis examined how changes in gender equality influenced smoking rates among 15–25-year-olds over 45-year-olds (Roczen et al.). As gender equality improved, smoking rates among young men and women became more similar, especially among those with a higher education. Another study analyzed U.S.-based Twitter/X public perceptions of the FDA's authorization of Vuse e-cigarettes (Lee et al.). It found that the majority of tweets were neutral, while negative posts which focused on health risks and criticized the decision, outnumbered positive ones. Although fewer, positive tweets often mentioned smoking cessation. Overall, the public discourse reflected more concern than support.

Reducing tobacco vendor density is an important measure for preventing tobacco uptake, especially among youth and for improving compliance with the law. A geospatial mapping study reported a high concentration of vendors, many violating tobacco control laws through sales to minors, advertising, and proximity to schools (Satpathy et al.). These findings highlight the urgent gaps in enforcement and the need for stronger policies. The tobacco industry has been using various tactics to influence health policy and increase its corporate social responsibility (CSR) efforts. One of the studies included here assessed India's efforts to reduce tobacco industry interference using the Global Tobacco Industry Interference Index (2019–2023) (Goel et al.). The findings report that while India initially improved its safeguards under WHO FCTC Article 5.3, that progress stalled in Goel et al.. The study calls for stronger regulations, greater transparency, and a unified government response.

Overall, these studies align well with the theme of the Research Topic, i.e., World No Tobacco Day, by emphasizing the need to curb the societal harms of tobacco and shift toward sustainable, health-centered alternatives.

Conclusion and way forward

Given that tobacco cultivation poses a triple threat to health, the environment, and food security, a shift toward sustainable agriculture would be an essential step toward climate resiliency and sustainable development in addition to being a public health necessity. This shift could be supported by phasing out tobacco subsidies, fostering cross-sector collaboration between health, agriculture, and environmental sectors, and implementing the WHO FCTC Articles 17 and 18. This could be done by investing in the transition of farmers from tobacco cultivation to food production (10–12), tackling industry interference and countering the misleading narrative that tobacco farming leads to affluence (12). This approach is critical to achieving the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Wellbeing) (13).

Author contributions

SG: Writing – review & editing, Methodology, Supervision, Conceptualization. GB: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Protecting public health and the environment: towards a general ban on cellulose acetate cigarette filters in the European Union

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After the establishment of a causal relationship between tobacco use and cancer in the 1950s, cellulose acetate filters were introduced with the claim to reduce the adverse health impact of unfiltered cigarettes. Often perceived to be more pleasant and healthy, filters encouraged smoking. However, filtered cigarettes are more deeply inhaled to obtain the same nicotine demand while altered combustion releases more tobacco-specific nitrosamines. The increasing use of cigarette filter ventilation is associated with a sharp rise in lung adenocarcinomas in recent decades. While not preventing adverse health effects, a global environmental problem has been created due to the non-biodegradable filter litter, causing ecotoxicological effects and the spread of microplastics. Recently, the Belgian Superior Health Council advised policymakers to ban cigarette filters as single-use plastics at both national and European levels. This article outlines the arguments used to justify this plea (human health and environment), the expected effects of a filter ban, as well as the public reception and reactions of the tobacco industry. The specific context of the European Union is discussed including the revision of the Single-Use Plastics Directive, affording a new opportunity to ban plastic filters. This perspective article aims to fuel the momentum and cooperation among member states for this purpose.

KEYWORDS

smoking prevention, tobacco, cigarette filter, adenocarcinoma, ecotoxicology

1. Introduction

Since the 1950s, a causal association has been established between tobacco smoking and lung cancer (1–3). Besides the presence of about 9,500 chemicals in cigarette smoke, 83 different IARC-classified carcinogens have been identified in unburned tobacco and tobacco smoke (4). A main response of the tobacco industry was the introduction of filtered cigarettes (with or without ventilation holes), although the history of the filter goes further back up to the 1860s

(5, 6). As filters can reduce tar, nicotine, and carbon monoxide (TNCO) intake per cigarette and particle concentrations (7–10), the industry actively promoted the idea that filters reduce health risks for smokers (11). This resulted in a false perception of greater safety among smokers of filtered, so-called "light" and "ultra-light" cigarettes (12–14). During the past three decades, the benefits of filters were disputed by many researchers and the WHO, with pleas for a filter ban growing louder (5, 6, 15–19). Moreover, controversy recently arose in the Netherlands about the presence of filter ventilation holes that dilute mainstream smoke. Due to their presence, standard ISO 3308 smoke machines used to assess cigarette emissions strongly underestimate the actual exposure of smokers to TNCO and aldehydes (20–22). This led to the Dutch term "*sjoemelsigaret*" (fraudulent cigarette), as the underestimation of the ISO method was formally affirmed by the Court of Rotterdam on November 4th, 2022 (23). In the context of these developments, the Belgian Minister of Environment asked an interdisciplinary working group of the Superior Health Council (SHC) for advice, which was published in April 2023, advocating a European ban on cellulose acetate filters (24). This position was supported by a broad front of national medical, paramedical, and patient organizations, and received wide coverage in Belgian media.

In this perspective article, it is aimed (1) to provide a scientific state-of-the-art of health and environmental arguments, (2) to discuss the expected effects of a filter ban, (3) to illustrate the reception of the Belgian initiative including reactions of the tobacco industry and (4) to discuss the specificity of the European institutional context for a filter ban, along with the next opportunity.

2. The health perspective

Given that filter use only increased exponentially since the 1950s and mid-1960s, the health effects of filters were poorly understood during the 20th century. This was complicated by lag times of lung cancer and possible epidemiological selection bias (e.g., sociological differences, smoking history and intensity). In 1986, the International Agency for Research on Cancer (Vol. 38) noted that some case–control and cohort studies (25–29) suggested greater risks for prolonged use of nonfilter and "high-tar" cigarettes (30). However, the IARC refrained from drawing premature conclusions. Due to the reduced particle numbers and TNCO per cigarette, filtered cigarettes are often perceived to be less harmful (12, 13). However, health issues should not be viewed on cigarette scale but as a function of individual nicotine demand. In 1989, Augustine et al. (31) noted that switching to filtered cigarettes may induce compensation behavior to meet the personal nicotine demand, increasing the total number of cigarettes smoked per day. Moreover, as filtered cigarettes reduce irritation, taste more pleasant and are perceived healthier, filters encourage people to smoke more cigarettes per day (12, 16). Compensation is indeed affirmed by human biomonitoring. When the number of cigarettes is taken into account, smoking-machine derived carbon monoxide (CO) and cyanide (CN) yields per filtered cigarette are not related to biomarkers such as carboxyhemoglobin levels, carbon monoxide in exhaled breath and urinary thiocyanate (32, 33). Moreover, for the same nicotine yield/cigarette measured by ISO smoking machines, a large variability in cotinine concentration exists between individuals (34), showing that the "cigarette scale approach" measuring TNCO is misleading both consumers and policy makers.

In the 1990s, researchers became increasingly aware of the potentially harmful side effects of filtered cigarettes as they seek to explain the alarming increase in lung adenocarcinomas during the 2nd half of the 20th century (35, 36). In 1950, the ratio of lung adenocarcinoma (AD) and squamous cell carcinoma (SQ) was 1:18 in the United States (36). While the incidence of SQ gradually decreased with a decreasing smoking prevalence of unfiltered cigarettes, the incidence of AD increased and exceeded SQ in the US in the 1990s (17). In 2010, the US AD:SQ ratio increased to 1:0.64 in men and 1:0.37 in women (37). Similar trends were also observed in Japan and Europe (38, 39). In 2020, the AD:SQ ratio for Belgian men and women was 1:0.59 and 1:0.25, respectively, (Figure 1). As filter ventilation alters cigarette combustion (longer burn time, lower temperature burn and less complete combustion) (17) and the nitrate content in tobacco blends increased, it was found that more tobacco-specific nitrosamines (TNSAs) are formed, which are more likely to induce peripheral lung AD (35, 36, 40–42). Typical carcinogenic TSNAs present in smoke are 4-(*N*-nitrosomethylamino)-1-(3-pyridyl)-1-butanone (NNK) and *N'*-nitrosonornicotine (NNN) (43). As predicted, compensation to meet nicotine demand appears to be a major contributor in this process: the more intense smoking pattern increased the amount of TSNAs 2- to 3-fold, while deeper inhalation and bigger puffs increased the delivery of TNSAs to the peripheral lungs (35, 36, 41). During the past 20 years, this hypothesis has only been reinforced by new research. Ito et al. (38) examined the relationship between tobacco use and lung cancer histology using tobacco consumption data and population-based incidence data from the US (1973–2005) and Japan (1975–2003). It was revealed that filtered cigarette consumption was positively associated with the incidence of AD, with lag times of 25 and 15 years in Japan and the US, respectively. In contrast, unfiltered cigarette consumption was positively associated with the incidence of SQ, with time lags of 30 and 20 years. Thus, with increasing AD, the average lag time for lung cancer decreased. In 2014, the Surgeon General's report on smoking and health concluded that the increase in AD was caused by the changing cigarette design. While the evidence was insufficient to specify which changes were responsible, it was indicated that "suggestive evidence" points to ventilated filters (37). In response to this report, Song et al. (17) performed an extensive weight-of-evidence review of both scientific literature and industry documents, leading to the conclusion that filter ventilation strongly contributed to the rise of AD. Increased filter ventilation also increased smoke mutagenicity in *Ames* tests (17). It was suggested that the FDA should consider regulating the use of filters, up to including a ban. These authors also discussed differences in lung cancer histology trends between both sexes. While in the US SQ in men declined since the late 1970s and was surpassed by AD in 1990, it was observed that AD has always been dominant in women and on the rise since 1970. The difference was explained by the fact that American women generally started smoking later in the century and usually smoked filtered cigarettes with lower tar contents (17). Given that the trends from the US are very similar to the incidence rates made available by the Belgian Cancer Registry (Figure 1), we suggest that this explanation also applies to Belgium. It can be concluded that the filter did not protect against lung cancer, but rather contributed to a shift in dominant histology from SQ to AD.

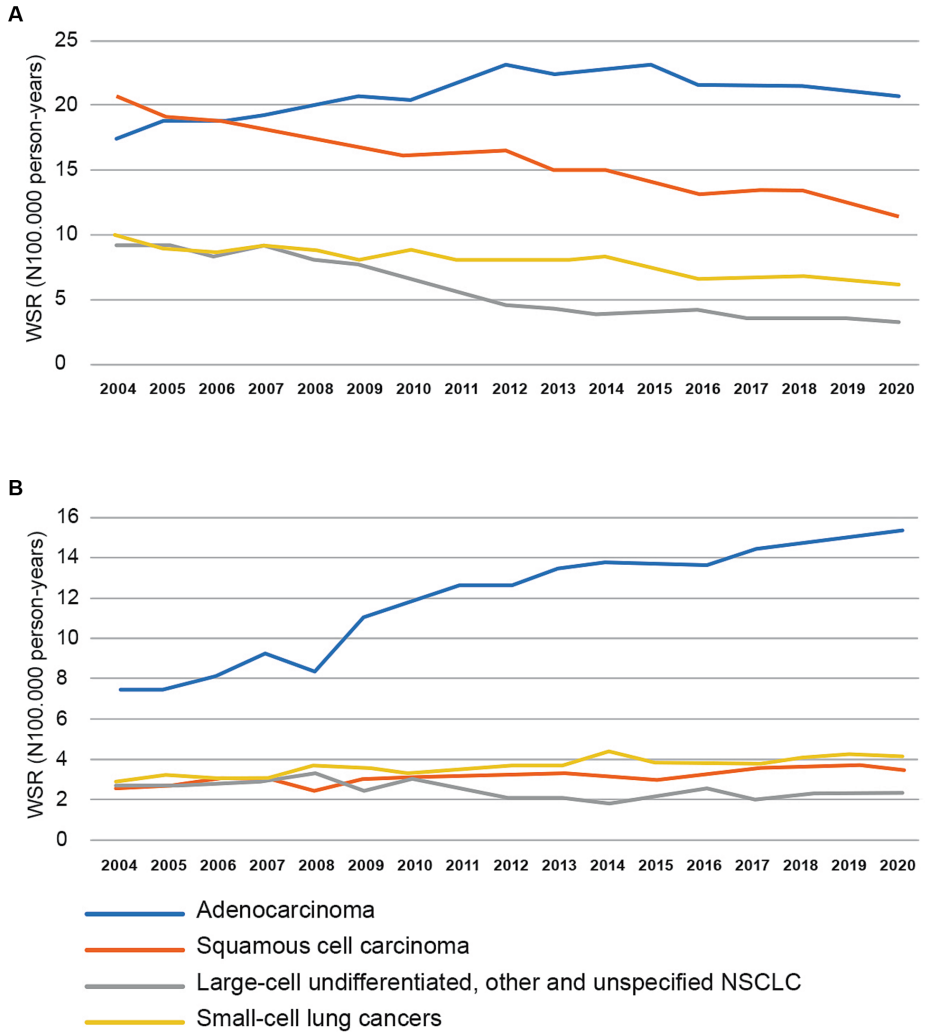

FIGURE 1
Trends in age-standardized incidence rates (using the World Standard Population) in Belgium from 2004 to 2020 for lung cancer for men **(A)** and women **(B)**. NSCLC = Non Small Cell Lung Cancer. Updated data provided by Belgian Cancer Registry (Brussels, 2023).

Data on the impact of filtered cigarettes on health effects other than lung cancer are relatively scarce. Some potential hazards such as inhaling cigarette filter fibers are not well studied and the health impact is simply unknown (44). A Chinese case-control study on the impact on oral squamous cell cancer showed overlapping confidence intervals (CI) between smokers of filtered (OR 1.30, 95% CI 1.15–1.48) and unfiltered cigarettes (OR 2.06, 95% CI 1.17–3.62) (45). CIs for filtered cigarettes (OR 2.19, 95% CI 1.19–4.03) and unfiltered cigarettes (OR 3.17, 95% CI 1.50–6.70) were also overlapping for chronic bronchitis in a cross-sectional prevalence study (46). In addition, for coronary heart disease (cohort study) (47) and oral leukoplakia (case-control study) (48), no significant protective effect could be established. Only in a study in subjects with dental implants, a significant increase in marginal bone loss was noticed on the mesial/distal surfaces in unfiltered heavy tobacco smokers (>20 cigarettes/day) (49). After all, the health disadvantage of smoking (both filtered and unfiltered) is much larger in each study, compared to not smoking. More than 70 years after awareness emerged on the causality between tobacco smoking and cancer, further health gains should only be obtained by smoking cessation, prevention and banning. It can be concluded that filtered cigarettes have no proven benefits in preventing adverse health effects of smoking. They create a false sense of security and encourage to smoke more. In that respect, they have been a brilliant marketing tool (6, 11, 15, 16, 19).

3. The environmental perspective

While filtered cigarettes have no proven benefits for human health, more than 90% of cigarettes sold worldwide are filtered (44). Globally, 6 trillion cigarettes are produced each year, 5.8 trillion cigarettes are smoked of which 4.5 trillion cigarette butts (CBs) end up in the environment (19, 50). Smoked filters are the most encountered littered item in the world. In Europe, cigarette filters represent 17% of all plastic items and 21% of all single-use plastics (SUPs) counted on beaches (51). In Flanders (northern Belgium), large-scale litter counts at 6,500 locations between 2019–2021 showed that CBs represent 41% of Flemish litter apiece, 2.5% by weight and

1.1% by volume (52). The small size of CBs makes it difficult to recover them during cleaning actions, leaving most butts in the environment. The current filter is a white plug consisting of 12,000 fibers of cellulose acetate, containing TiO_2 and the plasticizer triacetin (44). Cellulose acetate is a long-lasting material, as its biodegradation ability and rate are reduced with the increasing degree of acetylation, or even suppressed after a substitution degree above 2.5 (53, 54). Throughout the years, CBs undergo different physico-chemical fragmentation processes, leading to the formation of highly persistent microplastics in almost all natural compartments (55), probably threatening human health by entering the food chain (56). Biodegradation is further hampered by microbial nitrogen starvation (57) and the presence of toxic contaminants. As cigarette smoke contains more than 9,500 chemicals (4), a myriad of toxicants (including nicotine) retained by the filter leaches in the environment, stressing aquatic and terrestrial life. Despite the global effects, few studies are available (6). A review of 35 studies has been published by Green et al. (58), indicating that research on terrestrial life is lagging behind. This may be because terrestrial experiments with homogeneous exposure are more difficult to set up than in water.

A systematic review on aquatic organisms was published by Dobaradaran et al. (59), showing high toxicity of CBs impacting survival, growth and reproduction. Smoked filtered cigarette butts with tobacco remnants had higher mortality rates compared to unsmoked filtered cigarette butts for a frog species (*Hymenochirus curtipes*), different fishes (*Clarias gariepinus*, *Atherinops affinis*, *Pimephales promelas*) and tidepool snails (59). It is not surprising that smoked CBs are more toxic than unsmoked, given that the combustion process produces a lot of additional toxic products [e.g., Li and Hecht (4) identified 37 carcinogens in unburned tobacco, which rose to 80 in tobacco smoke]. Crustaceans appear more sensitive than fish, the water flea *Ceriodaphnia dubia* appears to be one of the most sensitive species (60). Recently, ecotoxicological experiments were undertaken in multiple master theses at the University of Antwerp. The amphipod *Grammarus pulex* was exposed by Van Roy (61) to the leachates of freshly collected CBs with tobacco remnants, displaying 96 h-LC_{50} ranges between 0.032–0.059 CB/L. Without tobacco remnants, a 96 h-LC_{50} of 0.1 CB/L was found (62). The pond snail *Lymnaea stagnalis* was studied by Steurbaut (63), exposed to complete CBs (96 h-LC_{50} 0.48 CB/L) and the tobacco fraction of CBs (0.27 CB/L). In a mesocosm experiment, lethal effects were only observed on *Asellus aquaticus* while sublethal effects were detected for the respiration rate of *Corbicula fluminea* (64).

The effects on terrestrial life are less pronounced, but still of concern. Green et al. (65) showed that CBs with filters reduce germination success and shoot lengths of *Lolium perenne* (perennial ryegrass) and *Trifolium repens* (white clover) and alter chorophyll a:b rates. Gill et al. (66) found that CBs may have low toxicity to soil-dwelling invertebrates, as cigarette butt effluent did not impact the survival, growth or feeding of the woodland snail *Aguispira alternata*. Although snails avoided CBs, avoidance decreased within a month along with declining toxicity. Another thesis at the University of Antwerp showed similar results: land snails (*Cornu aspersum*) exposed to print paper soaked in CB leachates showed no mortality or reduction in feeding rate, even at the highest concentration (50 CB/L) (67). Also, some observations have been made on terrestrial vertebrates, including song birds (68, 69). In urban areas, it was noted that some species use CBs in their nests as a repellent against ectoparasites. In both male and female house sparrows (*Passer domesticus*), genotoxic damage in red-blood cells was greater the more CBs were present in the nest.

All these studies show that the ubiquitous presence of toxic cigarette litter is a significant problem for various biota and compartments in different ecosystems. Unfortunately, multiple studies did not distinguish between the effects of the (burned) tobacco rod and the cellulose acetate filter itself, as >90% of the CBs contain a cellulose acetate filter. Therefore, it would be useful to see more ecotoxicological experiments with unfiltered cigarettes in the future.

4. The expected effects of a filter ban

Within the framework of single-use plastics, a general ban on cellulose acetate filters would reduce the microplastics burden in the environment. Unfiltered cigarettes thrown into the environment will equally release toxicants [e.g., nicotine, PAHs, VOCs, metals, phthalates (70)] that are a threat for biota. The release will possibly be even more intense but less prolonged. On the other hand, it can be assumed that the shorter "leftovers" will cause only a fraction of the environmental impact of current plastic CBs (71). Given that filters encourage smoking (15, 16), biodegradable filters are not preferred, as they could lead to "greenwashing" for the general population.

Cigarette filters fail to prevent adverse health effects. However, given the gradual shift from SQ to AD since their introduction, a reverse movement may be hypothesized after a filter ban. Both non-small cell lung cancers have a poor prognosis. For Belgian diagnoses between 2015–2020, 5 years survival was 30.2% (95% CI 29.4–30.9%) for AD and 25.1% (95% CI 24.0–26.1%) for SQ (Belgian Cancer Registry). On the other hand, lag times for AD are *ca.* 5 years shorter compared to SQ (38). According to the Belgian Cancer Registry, in 2020 for each histological type, the proportion of cases aged <50 years for AD is almost double that for SQ (men 8.7% vs. 4.9%, women 11.1% vs. 6.5%). As detection and treatment methods are constantly improving and evolving, it is difficult to make an accurate prediction of long-term trends. However, a further decrease in the prevalence of smoking can be expected by banning filters, as unfiltered cigarettes are perceived to be less pleasant, more irritable and unhealthier (11, 16). In a consumer survey in the Netherlands, 12% of the smoking respondents indicated that a filter ban would be a direct reason to quit smoking and to smoke less (71).

The Dutch consumer survey found that support for a filter ban is higher among non-smokers (63%) than smokers (35%) (71). Besides those who would quit or smoke less, 16% would start smoking unfiltered cigarettes and 18% would opt for home-made cigarettes with a reusable filter. Another 6% said they would start using other smoking products such as e-cigarettes, which could potentially lead to an increase in e-waste in the environment. While 27% of respondents were still undecided on their response to a ban, 18% said they would buy filtered cigarettes abroad and 8% illegally on the black market (71). The possibility of purchasing abroad can be largely avoided by implementing the ban at the EU level. The unwanted side effect of filtered cigarettes on the black market, in turn, is a concern for law enforcement and the fight against international criminal networks.

5. Public reception and reactions of the tobacco industry

Using these arguments, the SHC proposed a general ban on cigarette filters in April 2023, both on the Belgian and European level (24). As filters only encourage more smoking and give rise to microplastics and toxicants in the environment, it was stated that the filter should be treated as single-use plastics. To achieve maximum social awareness and media coverage, this viewpoint was reviewed and publicly supported by the Belgian Royal Academy of Medicine, the Belgian Society for Medical Oncology, the Belgian Respiratory Society, the Flemish Society of Respiratory Health and Tuberculosis Control, the Walloon Respiratory Fund, the Flemish Institute for Healthy Living, and Domus Medica, the Flemish GP association. The position was widely broadcasted in the national media (newspapers and television) (72) as well as in more specialized medical press (73, 74).

An immediate reaction from Philip Morris Benelux followed, considering the proposal "*unrealistic, ineffective and counterproductive*" (75). According to Philip Morris, the proposal would conflict with the EU's Tobacco Products Directive, distorting the single EU market and enabling criminal organizations to supply filtered cigarettes. While mainly legal and commercial objections are raised, no attempts were undertaken to disprove the scientific justification of a filter ban. In contrast, Cimabel (Cigarette Manufacturers of Belgium and Luxembourg) stated in a response to the Flemish public-service broadcaster VRT that "*Studies have shown that the lack of a filter leads to an increase in toxins inhaled by consumers. The filter ensures that cigarettes meet the prescribed levels of tar, nicotine and carbon monoxide*" (translated from Dutch) (72). The first argument falls back on the classic "cigarette scale approach" for TNCO, not taking into account compensation behavior and data from human biomonitoring (see Chapter 2). The second argument refers to the ISO smoking machines, which have recently been proven to underestimate the actual exposure of smokers to TNCO and aldehydes (20–23).

6. Discussion: how to proceed in a European context?

With the scientific arguments on the table, it is a political choice to introduce a general filter ban. However, the European context is very specific: competences are divided between national member states (including decentralized regional governments) and the European Union, each with its own courts. A recent study ordered by the Dutch government found that the legal feasibility of a ban at the individual member state level is very low, as large adaptions to the Tobacco Products Directive (2014/40/EU) (76) would be needed due to violations of the free movement of goods (Art. 24) (71). This was also highlighted by Philip Morris Benelux (75). Article 7 (7) of the Tobacco Products Directive imposes that member states should prohibit "*the placing on the market of tobacco products with flavourings in any of their components such as filters, papers, packages, capsules or any technical features allowing modification of the smell or taste of the tobacco product concerned or their smoking intensity*." Further specifying this article, cellulose acetate filters could also be explicitly included under this ban, as they make the smoke more pleasing and induce more smoking. Another, more viable option is the inclusion of a filter ban in the Single-Use Plastics Directive (EU) 2019/904 (77).

From 2021, the EU no longer allowed certain single-use plastic items to be placed on the member states market (e.g., plastic straws, stirrers, cutlery plates, cotton bud sticks). Despite cigarette filters being one of the main SUPs found in the environment, they were not included in this ban (15, 18). At the moment, the SUP directive targets reduction of cigarette filters due to marking and labelling requirements, extended producer responsibility and awareness-raising measures (78). Consumers are informed on the presence and effects of plastics in the filters, while tobacco companies should contribute to the cost of the cleaning and collection of filters. However, as cellulose acetate filters do not protect health, it is necessary to rectify this missed opportunity. In a recent letter (April 19th, 2023) from the Dutch Secretary of State for Infrastructure and Water Management to the Dutch Parliament, it is stated that the government is seeking cooperation with other member states to put a ban on filters on the agenda for the next revision of the SUP Directive in 2026 (79). With this initiative, it is our intention to foster this momentum so that policymakers can finally cross the Rubicon treating cigarette filters for what they are: a marketing tool causing global harm. In the meantime, primary prevention remains essential: no smoking should become the norm. In addition, it is known that adolescents and young adults who are aware of filters' environmental harm are more supportive of cigarettes sales bans (80). Therefore, specific education is needed on the environmental aspects of cigarette filters and microplastics among these groups.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

SE: Conceptualization, Project administration, Writing – original draft, Investigation. GS: Investigation, Supervision, Writing – original draft. FL: Investigation, Writing – original draft. AJ: Investigation, Writing – original draft. NL: Investigation, Writing – original draft. J-MR: Investigation, Writing – original draft. LB: Investigation, Writing – original draft. PS: Investigation, Supervision, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Public perceptions of the FDA's marketing authorization of Vuse on Twitter/X

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Introduction: On October 12, 2021, the FDA issued its first marketing granted orders for Vuse, the e-cigarette product by R.J. Reynolds Vapor Company. The public perceptions and reactions to the FDA's Vuse authorization are prevalent on social media platforms such as Twitter/X. We aim to understand public perceptions of the FDA's Vuse authorization in the US using Twitter/X data.

Methods: Through the Twitter/X streaming API (Application Programming Interface), 3,852 tweets between October 12, 2021, and October 23, 2021, were downloaded using the keyword of Vuse. With the elimination of retweets, irrelevant tweets, and tweets from other countries, the final dataset consisted of 523 relevant tweets from the US. Based on their attitudes toward the FDA authorization on Vuse, these tweets were coded into three major categories: positive, negative, and neutral. These tweets were further manually classified into different categories based on their contents.

Results: There was a large peak on Twitter/X mentioning FDA's Vuse authorization on October 13, 2021, just after the authorization was announced. Of the 523 US tweets related to FDA's Vuse authorization, 6.12% (*n*=32) were positive, 26.77% (*n*=140) were negative, and 67.11% (*n*=351) were neutral. In positive tweets, the dominant subcategory was *Cessation Claims* (*n*=18, 56.25%). In negative tweets, the topics *Health Risk* (*n*=43, 30.71%), *Criticize Authorization* (*n*=42, 30.00%), and Big Tobacco (n=40, 38.57%) were the major topics. *News* (*n*=271, 77.21%) was the most prevalent topic among neutral tweets. In addition, tweets with a positive attitude tend to have more likes.

Discussion: Public perceptions and discussions on Twitter/X regarding the FDA's Vuse authorization in the US showed that Twitter/X users were more likely to show a negative than a positive attitude with a major concern about health risks.

KEYWORDS

e-cigarettes, FDA, authorization, Twitter/X, Vuse

1. Introduction

Electronic cigarettes, officially called electronic nicotine delivery system (ENDS) but more commonly known as e-cigarettes, have a growing presence in the American population. Though e-cigarettes were only first introduced to the US market in 2006 as a healthier alternative to traditional cigarettes, their popularity has extended beyond the intended adult smokers (1). A recent 2021 study by the Center for Disease Control and Prevention (CDC) found that e-cigarettes have been the tobacco product of choice for American adolescents since 2014 (2).

In 2022 about 3.3% of middle school students and 14.1% of high school students admitted to current e-cigarette use (about 2.55 million in total), with 30.1% of those high school students and 11.7% of those middle school students admitting to using their e-cigarettes daily (3). The rate of e-cigarette use in youth is starkly higher than those of American adults, with only 4.5% of American adults reporting current use of e-cigarettes in 2021 (4).

Though the long-term health effects of e-cigarettes are only beginning to emerge, some symptoms of serious lung disease in people who have used e-cigarettes include cough, trouble breathing, chest pain, nausea, vomiting, diarrhea, fatigue, fever, or weight loss (5–8). A review of pre-clinical and clinical data from different studies determined that e-cigarettes use could have a negative impact on cardiovascular health (9–11). Despite this, a recent survey showed that most current e-cigarette users at least somewhat agree that e-cigarettes are a safe option for smoking cessation as well as safer than traditional and smokeless tobacco (12). As a result, the issue of ENDS products' position and validity in the American market has become a long battle in public health, but it has now become a legal matter. For any policy related to e-cigarettes, policymakers and public health authorities are trying to balance two public health objectives, preventing the initiation of e-cigarette use in youth or young adult non-smokers and reducing the harm of smoking for smokers through e-cigarette use (13).

On October 12, 2021, the US Food and Drug Administration (FDA) made a landmark decision by announcing the first official marketing authorization of three new ENDS products via the Premarket Tobacco Product Application (PMTA) (14). These grant orders were given to R. J. Reynolds (RJR) Vapor Company for its Vuse Solo e-cigarette device and three accompanying tobacco-flavored e-liquid pods. Given its technology and the results of a study where participants used the approved products, the FDA determined that the Vuse Solo and its accompanying e-liquid pods exposed users to fewer harmful and potentially harmful constituents (HPHCs), which are chemicals found in tobacco products that cause harm to both smokers and non-smokers (15). Further, the FDA assessed the risks and benefits of tobacco product users, non-users, and adolescents before concluding that the potential benefit for smokers drastically reduce or switch from traditional cigarette use outweighs the risk to youth and young adult non-smokers (14). With the FDA PMTA authorization of Vuse, it is important to understand how the public responds to this policy change on e-cigarettes.

Social media platforms such as Twitter (now re-branded as "X") have become a space for millions of users to post any content of their liking, and these posts have become a unique data source that displays the most current and updated public opinions and discussions. In comparison to other social media sites, Twitter/X data is more accessible and has become a valuable and abundant source. Twitter/X posts (tweets) have previously been used to examine and determine public perceptions of significant public health policies, such as the FDA's flavor enforcement policy and New York state policy on flavored e-cigarettes (16–19).

In this study, we aimed to understand public perceptions of the FDA's Vuse authorization using Twitter/X data by examining the attitudes and major topics discussed on Twitter/X. We manually labeled each relevant tweet from the US and categorized them into different attitudes and topics toward the FDA's Vuse authorization to better understand public perceptions. Our results will better inform future public health policy decisions.

2. Materials and methods

2.1. Data collection

Following the FDA's authorization of Vuse on October 12th, 2021, we collected all tweets relating to this authorization between October 12th, 2021, and October 23rd, 2021 through Twitter/X streaming API (Application Programming Interface) using the keyword "Vuse." A total of 3,852 tweets containing the keyword "Vuse" in either the text or hashtags were collected. After further filtering out retweets and duplicate tweets, we ended up with a dataset comprising 2,356 tweets.

2.2. Content analysis of tweets by hand-coding

To understand what might lead to different attitudes towards the FDA authorization of Vuse, we performed a content analysis on these tweets. For content analysis, we adopted the traditional inductive method in this study (20–22). From 2,356 tweets, a random sample of 300 tweets was hand-coded individually by two coders, which were used to develop a codebook (Supplementary Table S1). We only considered tweets that made explicit reference to the FDA's authorization of Vuse as a policy. We did not consider tweets that simply provided an opinion about any aspect of the Vuse product itself or other e-cigarette products.

All relevant tweets were grouped into three main categories based on the attitude of tweets toward the Vuse authorization announcement: positive attitude, negative attitude, and neutral attitude. All positive tweets were further grouped into four categories: cessation claims, celebration of the authorization, mocking those against the authorization, and other. "Cessation Claims" refers to tweets that expressed support for the FDA authorization of Vuse on the belief that the device would help traditional smokers quit cigarettes and that the device was a healthier alternative to cigarettes. "Celebration of the Authorization" refers to tweets that simply expressed a positive opinion or reaction to the news of Vuse's authorization. "Mocking Those Against the Authorization" is a category for tweets that not only expressed a positive reaction to the FDA authorization, but also mocked or made fun of other people/institutions that were vocal about their opposition. The positive category "Other" was reserved for tweets that expressed a positive attitude towards the authorization but did not provide an explicit reason. Many of these tweets used positive emoticons to express their support.

All negative tweets were grouped into five categories: health risk, criticize the authorization, complain about tobacco-flavored Vuse products, big tobacco, and other. "Health Risk" is a category of tweets that explicitly expressed concern for the impact on public health as a result of the FDA authorization of Vuse. "Criticize Authorization" refers to tweets that explicitly criticized or expressed disappointment about the FDA's decision to authorize the sale of Vuse. "Complain about tobacco-flavored Vuse products" includes the complain that

only tobacco flavor is available for Vuse and Vuse is an outdated product. "Big Tobacco" tweets explicitly drew a connection between Vuse's FDA authorization and the big tobacco industry, criticizing this potential conflict of interest. The negative "Other" category was reserved for tweets that expressed a negative attitude towards the authorization but did not provide an explicit reason. Many of these tweets used negative emoticons to express their criticism.

All neutral tweets were grouped into four categories: news, product safety claims, news on specific policies, or other. Tweets that fell into the "News" category were tweets of news article headlines or links that simply stated the fact that the FDA had authorized Vuse in the US market. Tweets under "FDA Claims About Product Safety" simply stated reasons the FDA cited for their decision to authorize Vuse. "Specific Policies" is a category for tweets that explicitly mentioned specific policies and product applications that contributed to the final FDA decision. The neutral "Other" category was reserved for tweets that did not fit into any of the previous neutral categories, in addition to not expressing a personal opinion or attitude towards the authorization.

For the first 300 sample tweets, the kappa statistic between the two coders was 0.91, indicating a high level of agreement. Any differences between the two coders were resolved through discussion by a group of four team members. The remaining 2,056 tweets were single coded by two coders.

2.3. Statistical analysis

We calculated the proportion of tweets with different attitudes toward the Vuse authorization, and their differences were tested using the two-proportional *Z*-test with a significant level at 5%. Within each attitude category, we also calculated the distribution of topics. We compared the average (with standard deviation) and median (with interquartile range) number of favorites (likes) of tweets for each attitude category and their respective topics.

3. Results

3.1. Attitudes towards the FDA authorization of Vuse on Twitter/X

From the 2,356 tweets we collected between October 12 and 23, 2022 using "Vuse" as the keyword, only 997 tweets were relevant to the FDA's authorization of Vuse. Of those 997 tweets, 523 tweets were posted by US Twitter/X users. Among these 523 tweets, 32 tweets (6.12%) showed a positive attitude towards the authorization, 140 tweets (26.77%) showed a negative attitude, and the remaining 351 tweets (67.11%) showed a neutral attitude (Table 1). The proportion of negative tweets was significantly higher than that of positive tweets ($p < 0.0001$). Figure 1 showed the distribution of relevant tweets between October 12th, 2022, and October 23rd, 2022. There was a peak on October 13th, 2022, with 237 tweets, which quickly decreased afterward.

3.2. Topics in tweets related to the FDA authorization of Vuse

As shown in Table 1, among positive tweets, the most popular topic was *Cessation Claims* ($n = 18$, 56.25%), followed by *Celebrate*

TABLE 1 Topics in tweets related to FDA's marketing authorization of Vuse.

Attitude towards the Vuse authorization (*n*, %)	Topics	Number of tweets (%)	Average number of likes (SD)	Median number of likes (IQR)
Positive (32, 6.12%)	Total	32 (100%)	9.56 (10.12)	6.5 (14)
	Cessation claims	18 (56.25%)	7.11 (8.07)	3 (12.5)
	Celebrate authorization	6 (18.75%)	7 (12.25)	1 (6.75)
	Mock those against authorization	5 (15.63%)	18.4 (5.9)	15 (7)
	Other	3 (9.38%)	14.67 (16.8)	11 (16.5)
Negative (140, 26.77%)	Total	140 (100%)	5.21 (13.15)	1 (4)
	Health risk	43 (30.71%)	5.19 (11.66)	1 (3)
	Criticize authorization	29 (20.71%)	7.82 (20.8)	1 (4)
	Complain about tobacco-flavored Vuse products	13 (9.28%)	5.69 (8.06)	4 (4)
	Big tobacco	40 (28.57%)	4.08 (11)	0 (2)
	Other	15 (10.71%)	2.87 (4.75)	0 (3.5)
Neutral (351, 67.11%)	Total	351 (100%)	3.62 (20.05)	0 (1)
	News	271 (77.21%)	2.54 (12.73)	0 (1)
	Claims about product safety	67 (19.09%)	5.90 (36.42)	0 (1.5)
	Specific policies	6 (1.71%)	23.67 (33.7)	4 (37.25)
	Other	7 (1.99%)	6.71 (10.01)	0 (11)

SD, standard deviation; IQR, interquartile range.

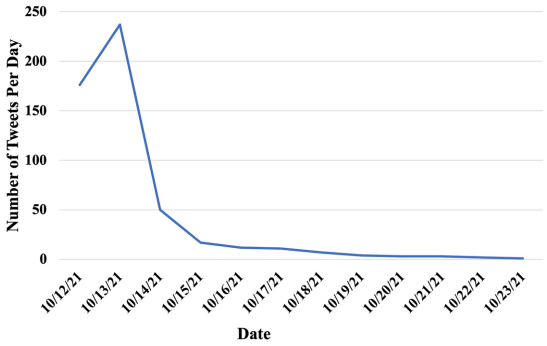

FIGURE 1
The longitudinal mentions of FDA's marketing authorization of Vuse on Twitter/X.

Authorization ($n = 6$, 18.75%), *Mock Those Against Authorization* ($n = 5$, 15.63%), and *Other* ($n = 3$, 9.38%). Among negative tweets, *Health Risk* ($n = 43$, 30.71%) and *Big Tobacco* ($n = 40$, 28.57%) were relatively popular, followed by *Criticize Authorization* ($n = 29$, 20.71%), Complain about tobacco-flavored Vuse products ($n = 13$, 9.28%), and *Other* ($n = 15$, 10.71%). *News* ($n = 271$, 77.21%) was the dominant topic in neutral tweets. Other neutral topics were less popular, such as *Claims About Product Safety* ($n = 67$, 19.09%), *Specific Policies* ($n = 6$, 1.71%), and *Other* ($n = 7$, 1.99%). Two days (since October 14th, 2022) after the announcement of Vuse authorization, the proportion of negative tweets increased (39.51%, 32/81). Among negative tweets, the proportion of "Criticize authorization" increased from 20.71% to 40.63% (Figure 2).

To examine how each tweet was viewed by other Twitter/X users, we examined the number of likes each tweet received. For positive tweets, the category *Mock Those Against Authorization* had the most likes (Table 1). For negative tweets, all four topics had a similar number of likes, though *Criticize Authorization* had the largest average (7.17) (Table 1). For neutral tweets, it is notable that *News* did not generate as many reactions as *Specific Policies* (Table 1). Table 1 also showed the median and IQR of the number of likes for each category: positive (median = 6.50, Interquartile Range (IQR) = 14), negative (median = 1, IQR = 4), and neutral (median = 0, IQR = 1).

4. Discussion

In this study, we examined public perceptions of the FDA's Vuse authorization by analyzing Twitter/X data. To our knowledge, this is the first study revealing how the public on social media perceived the Vuse authorization. Although most tweets were neutral, there were significantly more negative tweets than positive ones. The major reason for the positive attitude was that the Vuse authorization could help with smoking cessation. In contrast, the concern about health risks associated with vaping and the big tobacco company behind Vuse were the major causes for the negative attitude toward the FDA's Vuse authorization.

With the increasing popularity of e-cigarettes especially among youth, more concerns focused on the health risks associated with e-cigarettes. With the long-standing debate on if e-cigarettes are a safer alternative to combustible cigarettes, several studies have shown that e-cigarettes have relatively lower health risks than combustible cigarettes (23–25). In addition, aside from the gateway effect of e-cigarettes for cigarette smoking (26, 27), some studies have shown that vaping is considered an effective smoking cessation approach (28–30). In this study, we noticed that among positive tweets toward the Vuse authorization, the predominant theme was the discussion of lower health risks of e-cigarettes and their potential contribution to smoking cessation. This highlights a prevalent belief among certain Twitter/X users regarding the harm reduction benefits of e-cigarettes.

In this study, we observed that there were more tweets with a negative attitude than those with a positive attitude toward the Vuse authorization. In the category of *Health Risk*, Twitter/X users were concerned about health risks or the addictiveness of e-cigarettes as well as the unexpected e-cigarette use for those non-smokers especially among youth as a consequence of the Vuse authorization. The category *Complain about tobacco-flavored Vuse products* mainly complained about the lack of other flavors for approved Vuse products, or the company and product being authorized. Many were confused about why Vuse was being authorized, voicing that the Vuse Solo was an outdated e-cigarette product. The tweets in the *Big Tobacco* category expressed a notion that there was a corrupt deal between the FDA and RJ Reynolds due to the FDA's "loyalty to Big Tobacco company." Furthermore, tweets in the *Big Tobacco* category also wondered if the FDA cared about people using vaping as a means of smoking cessation, they would have chosen products that have lower nicotine content and that come from actual vaping companies. In addition, we observed that two days after the announcement of the Vuse authorization, the number of tweets discussing this policy dropped quickly, indicating that the public attention to this policy diminished quickly on Twitter. Interestingly, among those tweets, the proportion of negative tweets, especially those criticizing the Vuse authorization, increased significantly, which suggests that public perceptions of the Vuse authorization were evolving over time. Together, these tweets reflected that many Twitter/X users held a negative attitude toward the Vuse authorization because they were concerned about the health risks of e-cigarettes as well as the intention of authorizing Vuse products.

There were several limitations in this study. There were some challenges in determining which tweets were from US users. The user location feature is not always accurate, with some tweets or Twitter/X users not providing their location information or providing information unrelated to the location. Therefore, some tweets may not be accounted for since the user's location was not explicitly labeled as the US, which could introduce some biases. While we were trying to follow the best practice for category classification, we can not completely avoid some bias in this process. In addition, the sample size is relatively small in this study, which might limit the generalization of our findings. Moreover, the demographic composition of Twitter/X users, especially Twitter/X users who tweeted about this Vuse authorization, may not be the same as the US population. Therefore, our results may not accurately represent the attitudes of the overall US population. Lastly, since Twitter/X does not provide the demographics of Twitter users, we could not examine the responses to the Vuse authorization between different demographic groups (especially the adolescents), which need to be addressed in future work. How the Vuse authorization affected user behavior remains to be determined in future studies.

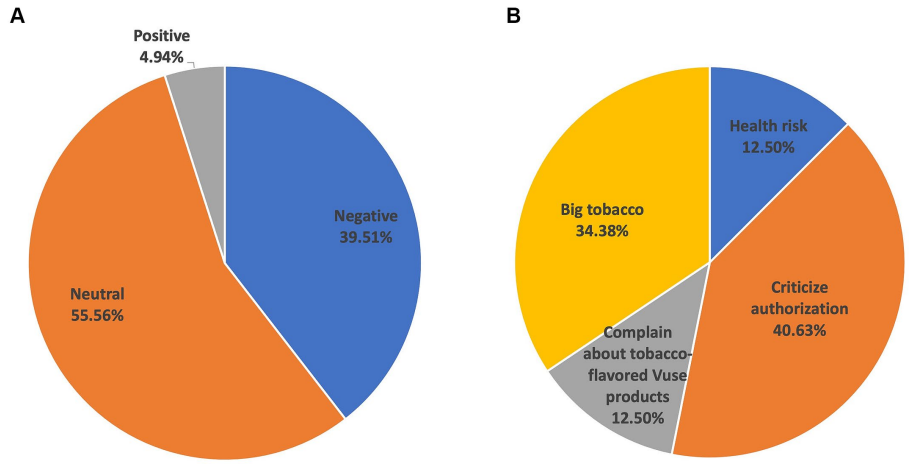

FIGURE 2
Topics in tweets related to FDA's marketing authorization of Vuse from October 14th, 2022 to October 23rd, 2022. **(A)** The proportion of tweets with different attitudes. **(B)** The proportion of topics in negative tweets.

5. Conclusion

By mining Twitter/X data, we examined public perceptions and discussions regarding the FDA's Vuse authorization in the US. We demonstrated that more tweets expressed a negative attitude toward the authorization than those with a positive attitude. Understanding how the public perceived and discussed the Vuse authorization could shed light on compliance with the authorization and potential changes in e-cigarette product use, which could help with future regulation of e-cigarette products.

Data availability statement

The Twitter/X data analyzed for this study are available upon request from the corresponding author.

Ethics statement

The studies involving humans were approved by this study has been reviewed and approved by the Office for Human Subject Protection Research Subjects Review Board (RSRB) at the University of Rochester (Study ID: STUDY00006570). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

SL: Formal analysis, Visualization, Writing – original draft, Writing – review & editing. ZX: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. EX: Formal analysis, Visualization, Writing – original draft, Writing – review & editing. YS: Data curation, Writing – original draft, Writing – review & editing. DO: Writing – original draft, Writing – review & editing. DL: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1280658/full#supplementary-material

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Use of electronic nicotine delivery systems and cigarette smoking—Add-on vs. displacement dual use

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KEYWORDS

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1 Introduction

Considering the health harms of tobacco smoking, the primary aim of individual and population-level interventions should always be cigarette cessation [i.e., "tobacco use pattern which involves the cessation of smoking cigarettes," defined by ADDICTO:0000649 (1)]. However, many smokers struggle to quit, and therefore replacing cigarettes with less harmful electronic nicotine delivery systems (ENDS) such as e-cigarettes can be helpful as a harm reduction strategy. While some people may switch completely, others might prefer dual use of combustible cigarettes and ENDS. Temporary dual use is not an argument against using ENDS as a smoking cessation aid. There is no clear scientific evidence that dual use either increases or decreases harmfulness beyond the level of combustible cigarette use. German guidelines on smoking and tobacco addiction recommend harm reduction through products with low toxicants emission, such as e-cigarettes, for people who smoke combustible cigarettes and are unable to quit smoking or do not want to (2). However, the guidelines also state that dual use leads to much less pronounced reduction in exposure to toxicants compared with completely switching to e-cigarettes. The authors conclude that there is a lack of evidence demonstrating the health impact of dual use due to limited studies in this area, which mostly suffer from methodological problems such as small sample sizes (2).

2 Add-on vs. displacement dual use

In contrast to the German guidelines' conclusions on dual use (2), Stokes et al. (3) observed no difference between dual users and those who exclusively smoked cigarettes based on biomarker data (inflammation and oxidative stress) of 7,130 US American adults who used combustible cigarettes, e-cigarettes, both, or none. Further, the researchers found no difference between adults who exclusively vaped and those who did not smoke or vape. Compared with regular cigarette smokers, vapers had significantly lower levels for almost all inflammatory and oxidative stress biomarkers (3). A secondary analysis of a Cochrane systematic review of trials of e-cigarettes for cigarette cessation also demonstrated that the biomarkers are lower when switching to e-cigarettes or dual use compared to combustible cigarette smoking (4). Nevertheless, critics of harm reduction repeatedly portray dual use as dangerous, and sometimes even more so than continued exclusive cigarette smoking (5, 6).

By using the term "dual use," guidelines suggest that there is a generally recognized definition of dual use that forms the basis of these studies and thus for guideline recommendations. However, this is not the case, as we will show below using the studies cited in the German guidelines [(7–10), see Table 1]. Rather, a distinction should be made between add-on use (where cigarette consumption is maintained but topped up with e-cigarettes, e.g., in situations that require temporary abstinence or similar) and displacement dual use (where some cigarettes are actually replaced by e-cigarettes) (11).

As the studies by Rostron et al. (8), Shahab et al. (9), and Keith et al. (10) were cross-sectional, it is unclear whether the behavior of dual users changed over time. It is possible that more dependent smokers may be more likely to become dual users and so actually reduce their higher cigarette consumption to levels similar to that of less dependent exclusive smokers. Longitudinal comparisons to assess changes in biomarkers have the advantage that researchers can follow up smokers before they start dual using. For example, Pasquereau et al. (12) followed up smokers (exclusive tobacco and dual use of tobacco and e-cigarettes) for 6 months. Those who used both products at baseline were more likely to reduce their cigarette consumption and attempt to quit smoking during the study than those who only smoked cigarettes at baseline. Kasza et al. (13) found that among smokers who were not intending to quit at baseline, those who started using e-cigarettes were more likely to stop smoking within 6 months than those who continued exclusively cigarette smoking. The same effect was observed with nicotine replacement therapy—when offered to smokers, even if they did not intend to quit, they were more likely to make a quit attempt than when not offered nicotine replacement therapy (14).

Using data from the Population Assessment of Tobacco and Health (PATH) Study conducted in the US between 2013 and 2014, Goniewicz et al. (15) observed two distinct usage groups among 792 dual users. One group smoked cigarettes and used e-cigarettes daily. This group could be labeled as add-on users. Another group used e-cigarettes daily but only smoked cigarettes on some days, so could be described as displacement dual users. The former group had significantly higher biomarker concentrations compared with the latter group. The authors concluded that the frequency of cigarette use among those consuming both products was positively correlated with nicotine and toxicant exposure (15). A study funded by Juul labs (an e-cigarette company) using the same PATH Study, but data collected in 2018/19, compared dual users who smoked <10 cigarettes per day ("displacement dual users") to those who smoked at least 10 cigarettes per day ("add-on users") (16). Toxicant levels of displacement dual users were lower than those of add-on users, while the levels of add-on users were comparable to exclusive cigarette smokers (16).

ENDS use is associated with a significant reduction in toxicants compared with the consumption of combustible cigarettes. The WHO, known to be rather critical of e-cigarettes, stated in its report on electronic nicotine and non-nicotine delivery systems (EN&NNDS): "There is conclusive evidence that: completely substituting EN&NNDS for combustible tobacco cigarettes reduces users' exposure to numerous toxicants and carcinogens present in combustible tobacco cigarettes; . . . " (17). The International Agency for Research on Cancer, which forms part of the WHO, states on their website (18): "E-cigarettes have the potential to reduce the enormous burden of disease and death caused by tobacco smoking if most smokers switch to e-cigarettes and public health concerns are properly addressed." Despite this encouraging assessment, many consider the simultaneous consumption of combustion cigarettes and ENDS as harmful, and the risk of so-called dual use is cited as a strong argument against recommending ENDS use (5, 6). As stated above, the term dual use is not generally well-defined and negative effects of dual use beyond those of exclusive cigarette smoking have not been scientifically substantiated. One can speak of dual use in a completely neutral way when two products are used side by side. However, this is not suitable for scientific evaluation. It is important to distinguish between smokers who have not changed their cigarette smoking pattern but who additionally started using ENDS and those who replaced some of their combustible cigarette consumption through ENDS use. The former could be defined as "add-on use" and the latter as "displacement dual use."

Add-on use, commonly associated with higher nicotine dependence (19, 20), is not recommended as it does not reduce the level of toxicants inhaled. In contrast, displacement dual use reduces the inhaled concentration of toxicants compared with obtaining the same amount of nicotine by smoking cigarettes exclusively (3, 4, 7–10). The idea of harm reduction in the context of smoking means that people should reduce their cigarette consumption as much as possible by switching to alternatives that contain less harmful toxicants. The publications summarized above have demonstrated that add-on use is not generally associated with an increased concentration of biomarkers (3, 4, 7–10). The measured values correlated with the number of combustible cigarettes consumed. With displacement dual use, on the other hand, the concentration of carcinogens in the urine decreased in line with the decrease in the number of combustible cigarettes smoked, suggesting that ENDS use did not measurably contribute to additional toxicant intake.

3 Displacement dual use as a cigarette cessation aid

The European Union and its member states have been trying for years to curb the consumption of tobacco and related products through different measures, including regulations, restrictions on advertising and sponsorship, smoke-free zones, and anti-smoking campaigns. The European Commission regularly conducts opinion polls to gauge Europeans' attitudes toward tobacco-related issues. These polls showed that e-cigarettes and heated tobacco products did not contribute to smoking uptake. A US study (21) using data from the Tobacco Use Supplement to Current Population Surveys and the National Health Interview Survey found that from 2014/2015 to 2018/2019, exclusive ENDS use increased while exclusive cigarette and dual use of ENDS and cigarettes decreased [in the US, dual use primarily fits our definition of add-on use (22, 23)]. In agreement with studies (12, 13) cited above, a 24-month study on the consumption of tobacco and e-cigarettes among young adult binge drinkers showed that dual use is often a transitional phase between cigarette smoking and cessation (24). The latent transition analysis revealed four distinct user patterns among young adults from the US and Canada: (1) exclusive e-cigarette use,

TABLE 1 Studies on dual use cited in German guidelines on smoking and tobacco addiction.

References	Study design	Findings and comments
Czoli et al. (7)	Open-label crossover design ($n = 48$) comparing four different scenarios for seven days each: (1) dual use, (2) cigarette use, (3) e-cigarette use, and (4) no product use.	During the entire study, participants used both products to some extent. The period defined as "dual use" fits our description of "add-on use" since participants did not smoke fewer cigarettes than during the week of exclusive cigarette use. During the week of exclusive e-cigarette use, participants reduced their cigarette consumption notably and, hence, had lower levels of carcinogens compared with the cigarette smoking week. Add-on use of e-cigarettes while maintaining similar cigarette consumption did not increase the concentration of measured carcinogens in urine.
Rostron et al. (8)	Cross-sectional study ($n = 2{,}700$) as part of the Population Assessment of Tobacco and Health (PATH) Study. Participants were categorized into three groups: (1) only cigarette use, (2) dual use of cigarettes and e-cigarettes, and (3) dual use of cigarettes and smokeless tobacco.	The so-called dual users in the second group smoked the same number of cigarettes per day as those who exclusively smoked cigarettes, so the term "add-on use" would have been more appropriate. The add-on use of e-cigarettes to the daily number of smoked cigarettes did not significantly change the urine concentration of a relevant biomarker. This effect was independent of the number of cigarettes smoked.
Shahab et al. (9)	Cross-sectional study ($n = 181$) including: (1) exclusive cigarette smokers, (2) former smokers with long-term ($\geq$6 months) e-cigarette-only, or (3) nicotine replacement therapy-only use, and (4) long-term dual users of combustible cigarettes with e-cigarettes or (5) with nicotine replacement therapy.	The group of dual users smoked, on average, only 2 or 3 fewer cigarettes per day than the group of exclusive smokers, consistent with some minimal displacement. The long-term switch from cigarette smoking to e-cigarette use was associated with significantly lower concentrations of specific carcinogens and toxicants compared with continuous cigarette smoking, while no differences were observed between dual users and exclusive smokers.
Keith et al. (10)	Cross-sectional study ("Cardiovascular Injury due to Tobacco Use Trial," $n = 371$) including: (1) non-users, (2) exclusively ENDS users, (3) cigarette smokers, or (4) dual users based on their past 30-day consumption.	Smokers and dual users had comparable volatile organic compound metabolite levels. The reported smoking patterns of the two groups did not seem to differ too much in terms of the mean number of daily cigarettes smoked in the past 30 days. Therefore, at least for some study participants, the term add-on use might be more appropriate.

(2) dual use, (3) exclusively combustible cigarette smoking, and (4) non-use. Most of the dual users switched to complete abstinence or to the exclusive consumption of e-cigarettes. For smokers who used only combustible cigarettes, the most common transition was abstinence, followed by those who remained in the group of combustible cigarette smoking. After 24 months, 63% of exclusive e-cigarette users transitioned to abstinence, 37% continued to use e-cigarettes, and none transitioned to dual or combustible cigarette use (24).

The German DEBRA study showed that e-cigarette use was associated with higher odds of successful quitting than nicotine replacement therapy use or no aid (25). A study from New Zealand assessed smoking and vaping patterns in people who smoked cigarettes but were not currently using ENDS or were using them less than once a week, not currently attempted to quit, and had never tried to quit through using ENDS for 30 days or more (26). Participants received an ENDS device at the beginning of the study and were asked to report their use over 20 weeks. Most participants reported different consumption levels of combustible cigarettes and ENDS throughout the study period, which also included phases of dual use. The authors concluded that the considerable diversity in alternate use observed within and between study participants suggests that the high variability is typical rather than exceptional. The transition from smoking to ENDS use may involve significant periods of dual use that are likely to be dynamic and may span several months (26).

In qualitative interviews, Notley et al. (27) found that some former smokers started using e-cigarettes without attempting to quit combustible cigarette smoking but slowly transitioned by replacing some of their cigarettes through e-cigarette use, and eventually found more pleasure in e-cigarettes than in combustible cigarettes. Because e-cigarette use, unlike other nicotine replacement products, can substitute psychological, psychosocial, and social aspects of combustible cigarette smoking, it may be more suitable to help some smokers quit cigarettes than other nicotine replacement products. In addition, e-cigarettes offer unique features for smoking relapse prevention (27, 28).

4 Conclusions

Unfortunately, there is no recognized definition of dual use in the scientific literature that differentiates between what we term add-on and displacement use dual use. The studies on the topic of dual use listed in the German guidelines on smoking and tobacco dependence illustrate this dilemma clearly. In most of these studies, what is referred to as dual use likely represents add-on use. At the same time, however, these studies also show that even add-on use, regardless of the form in which it is practiced, does not lead to higher levels of toxicant exposure for the consumer than consumption of combustible cigarettes alone. Dual use and add-on use are not the goals of cigarette cessation strategies. The primary goal is the complete cessation of cigarettes.

From a health perspective, people would ideally quit all nicotine-containing products. However, for those who cannot achieve this, a full switch to ENDS makes sense, and temporary dual use is not a good argument against using ENDS as an aid to achieve abstinence from cigarette smoking, especially if it leads to later cessation of all nicotine-containing products. There is no scientific evidence that dual use is more harmful than combustible cigarette use if the number of cigarettes smoked remains the same. Therefore, we suggest that the adoption of agreed standards would help to evaluate the consequences of add-on and displacement dual use, respectively. A clearer differentiation would not just be of scientific value but could guide decision-making in clinical practice. Temporary displacement dual use should be evaluated differently than permanent displacement dual use or even add-on dual use. These dual users likely require a different approach to successfully achieve cigarette cessation. If research continues to show that displacement dual use reduces exposure to harmful toxicants compared to exclusive cigarette smoking and potentially increases chances of quit success, it should be recommended by guidelines as a harm reduction tool. After all, the aim of interventions should be to reduce the harm, with abstinence as an ultimate ideal but not a requirement.

Author contributions

KK: Conceptualization, Writing—original draft. VB: Writing—review & editing. LS: Writing—review & editing. MS: Writing—review & editing.

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Conflict of interest

LS reports receiving honoraria for talks, receiving an unrestricted research grant and travel expenses to attend meetings and workshops by pharmaceutical companies that make smoking cessation products (Pfizer and Johnson & Johnson), and acting as a paid reviewer for grant-awarding bodies and as a paid consultant for health care companies. He has never received personal fees or research funding of any kind from alcohol, electronic cigarette or tobacco companies.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Gender equality and smoking among 15 to 25 year olds—a time-based ecological analysis of developments in Germany from 1960 to 2005

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Introduction: Smoking is a major risk factor for premature death and health problems in which there are significant gender differences in the prevalence of smoking. This ecological study examines the correlation between changes in gender equality and prevalence of smoking among young adults (15–25 years old) in Germany over a period of 45 years (1960–2005).

Methods: Gender inequality was measured using the United Nations Gender Inequality Index (GII), which is composed of three dimensions; health, empowerment and labour market. It was calculated for the entire registered German population in five-year intervals with values between 0 and 1 (1 = highest inequality). The smoking prevalence of young women and men in Germany was established using a reconstruction method. A gender smoking ratio (GSR) with values between 0 and 1 was determined (1 = identical smoking prevalence among men and women). The smoking behaviour was illustrated and stratified by education. The correlation between the GII and the GSR was analysed.

Results: The GII decreased from 0.98 to 0.56 between 1960 and 2005. The GSR increased from 0.34 to 0.93. There was a strong negative correlation between the GII and the GSR ($r = -0.71$). The strength of the correlation fell slightly as the level of education decreased. An increase in gender equality as measured by the GII came along with similarities of smoking prevalence between young women and young men.

Conclusion: Successful tobacco prevention among young women and men may benefit from involving experts in gender-specific public health research to develop counter-advertising and gender-specific information as needed.

KEYWORDS

smoking, smoking prevalence, gender equality, gender inequality, young adults, time-based, tobacco control, Germany

Introduction

Smoking is one of the leading risk factors for premature deaths and health issues worldwide (1). Germany ranks ninth out of 195 countries in smoking prevalence among people aged 10 and older and 13th among the subpopulation of adolescents aged 15 to 19 (2). In 2019, 6.3% of the female and 8.0% of the male adolescents aged 12 to 17 years considered themselves smokers. In the age group 18 to 25, 23.7% of female and 33.4% of male young adults smoked (3, 4).

From a Public Health point of view, it is important that adolescents do not take up smoking in the first place (smoking initiation). In Germany, there are programmes and educational work by the Federal Centre for Health Education that are specifically designed to prevent young people from starting to smoke or to support them in quitting (5, 6). Young adults are likely to be more impulsive and self-confident than adults due to the neurobiological changes during this developmental phase (7). Thus, they are particularly vulnerable to harmful products that offer instant gratification, a sense of adventure or social status. Harmful products may pose a higher risk to young adults than to adults due to the rapid changes in the adolescent brain, for example through a higher likelihood of becoming addicted (7).

Tobacco industry advertising contradicts the idea of prevention. A report from Germany shows that young adults especially are susceptible to the perception of tobacco industry's promotional activities (8). Despite bans on tobacco advertising, for example on television, radio or through print media or product placements, many tobacco advertising measures are still permitted in Germany. Outdoor and point-of-sale advertising, as well as advertising in cinemas after 6 pm and direct marketing for tobacco are currently allowed. As a consequence, young adults in Germany are inevitably exposed to tobacco advertising campaigns in a variety of settings (9).

The marketing strategies employed by the tobacco industry are also adapted to appeal to prevalent motivations for smoking among young adults. Tobacco advertising markets the use of tobacco products to achieve well-being, popularity, relaxation or companionship with tobacco products, for example. In addition, advertising specifically addresses gender issues among young adults (10). Thus, for boys the feeling of belonging to a peer group, to 'be cool' or to feel grown up seems to be a particularly prominent motivation for smoking. For girls, it is more often about weight reduction, attracting attention, rebelling against parents or teachers, and relaxation (11). Therefore, these differences in motivation and smoking behaviour are likely to be influenced by prevailing gender norms and roles. Gender is defined by a multidimensional social construct that is constantly changing and that characterises boys and girls, and men and women in their norms and roles within a group or society (12). Gender roles describe a construct where cultures and societies have expectations about the roles and behaviour of boys and girls and men and women which in turn promote gender-specific behaviour (13). Sex and gender differences can be seen in the socio-cultural use of tobacco products ("gender") and in the biological reaction to tobacco consumption ("sex"). Both aspects interact with each other and influence smoking initiation as well as general smoking behaviour (e.g., currently smoking or not, frequency) and quitting behaviour (14).

The smoking behaviour of young women and men in Germany differs and has changed over the course of time depending on social status. In the past century, there has been a shift from higher smoking prevalence in higher to lower social status in Germany, which was observed earlier in young men than in young women (9). In this context, children and adolescents (11–17 years) hardly showed any differences in smoking behaviour between the sexes and the educational differences in smoking behaviour were similar for both sexes. Young adults (18–25 years) as well as adults (>25 years) on the other hand showed differences in smoking behaviour between genders with educational differences in smoking behaviour being similar for both genders (15, 16). Comparisons in other European countries also show that men with a lower educational status have a higher prevalence of smoking than those with a higher educational status. This gradient between the different education groups is more distinct in younger age groups, and is also a trend that is discernible among younger women (17–20).

Gender analyses in health, including smoking initiation and smoking behaviour, should examine the extent to which gender inequality influences health behaviours (21). Gender inequality exists when boys, girls, men, and women have unequal opportunities to achieve their potential, for example in terms of their health. This study investigates the temporal changes in gender inequality, measured by the United Nations Gender Inequality Index (GII), the prevalence of smoking, and a gender smoking ratio (GSR) among young adults (defined as the 15-25-year age group) in Germany between 1960 and 2005. A particular concern of the present study was to calculate smoking prevalence only among young adults who smoke tobacco cigarettes. In order to maintain theoretical and analytical accuracy, we consider it necessary to exclude products such as e-cigarettes, which have only been available on the European markets since 2006 (22). According to a survey conducted in 2006, 1.4% of respondents regularly used e-cigarettes at that time. Among smokers, 32.7% had ever tried e-cigarettes. Of those who had never smoked, 2.3% had ever tried e-cigarettes (23). Smoking products other than tobacco cigarettes are likely to be associated with different smoking behaviour in general, which in turn may influence gender-specific smoking patterns. At this stage, some gender differences in the prevalence of e-cigarettes compared to tobacco cigarettes can already be identified among young adults (22). The specific reference to tobacco cigarettes counteracts a possible bias that could result from the change in gender-specific smoking prevalence throughout the study period due to the introduction of tobacco-free smoking products at a later stage. The GII has mainly been used to compare different health contexts in different countries or populations, but it was also used for a regional gender differences in life expectancy in the European Union (24–28); however there is a paucity of studies on the temporal evolution of the index within a population, and the correlation between the GII and smoking behaviour in a country. This study determines the relationship between the GII and the GSR, considering also education as a stratifying factor to assess gender inequality in Germany and its association with the smoking behaviour of young women and men and to illustrate changes over time.

Abbreviations: FRG, Federal Republic of Germany; GDR, German Democratic Republic; GEDA, German Health Update study; GII, Gender Inequality Index; GSR, Gender smoking ratio; ISCED, International Standard Classification of Education.

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Materials and methods

This ecological study is derived from two different data sources. The data on the prevalence of smoking, the GSR, the education level and the birth year based on the German Health Update study (GEDA) by the Robert Koch Institute, the national public health authority in Germany. The GEDA study is a representative survey of the German-speaking adult resident population in private households with a landline connection. The GEDA study, which is regularly repeated as part of health monitoring, is aimed at the continuous observation of developments in the incidence of disease and in health and risk behaviour and is intended to contribute to providing health reporting and health policy with timely information to identify health trends in the population or in population groups. For this current study, data from the surveys conducted in 2009, 2010 and 2012 of the GEDA were pooled, resulting in a total of 33,720 participants. The analyses are limited to 15 to 25-year-olds in each of the years studied. This resulted in a population between $n = 9{,}425$ and $n = 14{,}000$ in the years 1960–2005. The population of young men aged 15–25 years ranges between 3,968 and 6,755 in the years from 1960 to 2005. The population of young women at the same age is between 4,448 and 8,342 in the same time period.

The German Federal Statistical Office (Statistisches Bundesamt) provided the aggregated population data used for the calculation of the GII. This includes data on education and labour force participation based on the German micro-census. Data concerning maternal mortality is based on the cause-of-death statistics, while the fertility rate of adolescents was derived from the German population statistics. The data used to calculate the proportion of men and women in parliament was gathered from a data manual on the history of the German parliament (29).

Gender smoking ratio

The prevalence of smoking for calculation of a GSR was determined using weighted data from the GEDA study, which examines the association between health and lifestyle of adults in Germany. The survey was conducted by means of telephone interviews (30–33). The study participants are representative for the German population aged 18 years and older. In this study the analyses are limited to 15 to 25-year-olds. All participants who completed the relevant items of the questionnaire were included in the analyses. Smoking status was categorised into non-smoker, current smoker and ex-smoker [Questionnaire scheme: Do you currently smoke—even if only occasionally? Current smokers (1 = Yes, daily and Yes, occasionally) were asked: How old were you when you started smoking, even if only occasionally? And what do you smoke? You could also give more than one answer. Ex-smokers (2 = No, no longer) were asked: Did you used to smoke once a day? And what did you smoke in the past? You can also give more than one answer. How old were you when you stopped smoking?]. Excluded from the analyses were participants who exclusively smoke cigars or pipes as they represent only a very low percentage of the German population (9). Participants who stated that they had been younger than 11 years old when they started or quit smoking were also excluded, as statistics in Germany on the prevalence of smoking often start at the age of 11. This means that the data can be directly compared. In Germany, it is also the case that children under the age of 11 attend elementary school and move on to secondary school at the age of 11 and are therefore exposed to different peer groups and different impressions.

The prevalence of smoking was reconstructed for each calendar year between 1960 and 2005 using the method introduced by Harris (34) to simulate the data. For this, each participant was assigned a smoking status (smoker/non-smoker) for each calendar year. Non-smokers are considered as such for the entire period, while current smokers are regarded as smokers from the year in which they started smoking until their current age. Former smokers are categorised as smokers from the time they started smoking until the time of quitting; before and after that time, they are counted as non-smokers. Smokers who did not answer when they took up smoking are assigned the average age of smoking initiation from their birth cohorts. Former smokers who did not indicate ever giving up smoking are classified as smokers until the end of this study period (2005).This means for example, that an individual smoker who reported in the 2010 survey that he or she was born in 1970 and smoked between the ages of 18 and 35 will have the following statuses: From 1981 to 1987 (ages 11–17), this person will be counted as a non-smoker. From 1988 to 2002, the person reported smoking and is therefore recorded as a smoker in these years. From 2002 until the end of the study period, the person is again classified as a non-smoker. In order to determine the prevalence of smoking for each calendar year between 1960 and 2005, the number of smokers was divided by the total population of 15-25-year olds in the corresponding calendar year (34).

To calculate a female-to-male GSR, the prevalence of smoking in young women was divided by the prevalence of smoking in young men. Values below 1 describe a higher prevalence of smoking in young men, value equal 1 means identical smoking prevalence among men and women, values above 1 correspond to a higher prevalence of smoking in young women (35).

Educational status

The education data also comes from the GEDA data and are used for stratification in this study. Data on school and vocational education of the respondents was collected, in order to calculate the education groups according to the ISCED classification (International Standard Classification of Education) and categorised into low, middle and high educational status (36).

Gender Inequality Index

The GII describes the extent to which the human development potential of a country is influenced by gender inequality (37). The index assumes values between 0 and 1, with values closer to 0 corresponding to less gender inequality and more human development potential (37). The index includes three dimensions: health, empowerment, and the labour market. The *health* dimension measures maternal mortality (per 100,000 live births) as well as adolescent birth rates (number of births per 1,000 women aged 15 to 19 years). The *empowerment* dimension consists of two indicators: the proportion of the population aged 25 and older with at least a secondary-level education and the distribution of female and male members of the

parliament. The dimension *labour market* describes the labour force participation rates of males and females (ages 15 to 64 years) (37). A person is defined as employed when they are aged 15 years and over and (a) work at least 1 hour a week for remuneration, (b) are self-employed in a trade, or (c) work in a family business without being paid.

All indicators were generated in five-year intervals for the period from 1960 to 2005. Data on education was available for the years 1961, 1970, 1976, 1980, 1985, 1989, 1991, 1995, 2000, and 2005 and averaged over the adjacent values for the intervening periods. In order to calculate a GII for 1960, the data for education from the following year was used. For the period from 1960 to 1989, only indicators for the former Federal Republic of Germany (FRG) are provided by the German federal statistical office. Data from the former German Democratic Republic (GDR) were therefore not included in the analyses. As of 1990, the data include Germany as a whole. For the calculations of the GII, the requirements from the UN Human Development Report 2011 were applied (37).

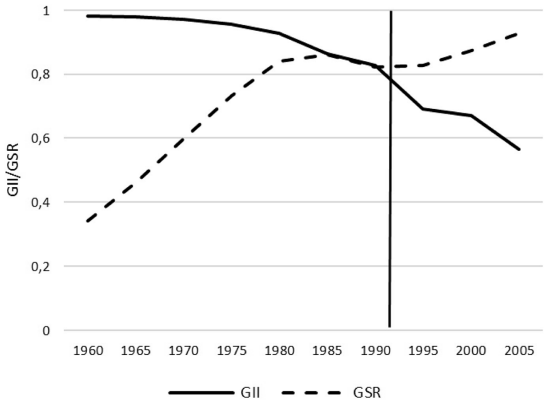

FIGURE 1
Gender inequality index (GII) and gender smoking ratio (GSR) from 1960 to 2005 in Germany.

Statistical analyses

In this ecological study the temporal changes of GII and GSR as well as prevalence of smoking of 15-25-year-old young women and men over the period from 1960 to 2005 in Germany was illustrated using descriptive statistics. The smoking prevalence also was stratified by educational status and was descriptively presented from 1960 to 2005. Correlation between GSR and GII was assessed using Pearson correlation coefficient. A significance level of 0.05 was defined for the analyses. SAS® 9.4 was used to conduct all analyses (SAS Institute Inc., Cary, NC, United States). All figures were created with Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, United States).

Results

Temporal trends in gender inequality index and its components

The GII showed a decline from a maximum value of gender inequality at 0.98 to a minimum of 0.56 from 1960 to 2005 (Figure 1; Additional file 1).

The components of the GII showed the following trend: The **maternal mortality** per 100,000 live births decreased from 1,030 maternal deaths per 100,000 live births in 1960 to a maternal death rate of 28 per 100,000 in 2005. The **adolescent birth rate** initially increased from 1960 to 1970 from 22 to 36 births per 1,000 women aged between 15 and 19 years and then dropped to eight births per 1,000 women by 2005. The **proportion of female and male individuals with at least secondary education** was very similar and increased from less than 10% to almost 50% during the investigated time period. The proportion of women with at least secondary education was slightly lower than that of men throughout the entire study period. The **distribution of seats in the German parliament** showed a consistently large difference between men and women between 1960 and 1985, with the proportion of men between 90 and 94% and women, conversely, between 10 and 6%. From 1990, the proportion of men declined from around 80 to 68% in 2005. For women, a parallel increase to around 32% could be observed. The **female labour force participation** rate increased from 42 to 51% from 1960 to 2005. At the same time, the male labour force participation rate dropped from 82 to 66%. While labour participation among men in 1960 was about twice as high as the rate of women, in 2005 about one third more men than women worked (Figure 2; Additional file 2).

Smoking prevalence and gender smoking ratio

The GSR increased continuously from 0.34 in 1960 to 0.93 in 2005 (Figure 1; Additional file 1). Over this monitored period, the prevalence of smoking among young women approached that among young men. Overall, there are fluctuations of about 10% in the smoking prevalence of young men between 1960 and 2005. In young men, the prevalence of smoking increased from 45% in 1960 to 55% in 1975. After that, it briefly remains constant and then declines to 50% after 10 years. Until 2004, the value fluctuates slightly between 49 and 52% and then drops to 47% in 2005. The prevalence of smoking among young women tripled from 15 to 45% from 1960 to 1985. The smoking prevalence then decreases to 40% until 1994 and before rising again in the following 10 years to 46%. In the last 2 years of the studied period, the prevalence of smoking is approximately 44% (Figure 3; Additional file 1).

Smoking prevalence by education

Among both, young women and men, smoking prevalence increases with decreasing educational level. In all education groups, the prevalence of smoking is lower among young women than among young men. The smoking behaviour of young men was constant during the period being examined: Young men with a low and middle educational status smoked consistently more than young men with a higher educational status. From 1969 onwards, a consistent picture is evident: the higher the educational status, the lower the smoking prevalence. From the year 2000 onwards, the smoking prevalence of

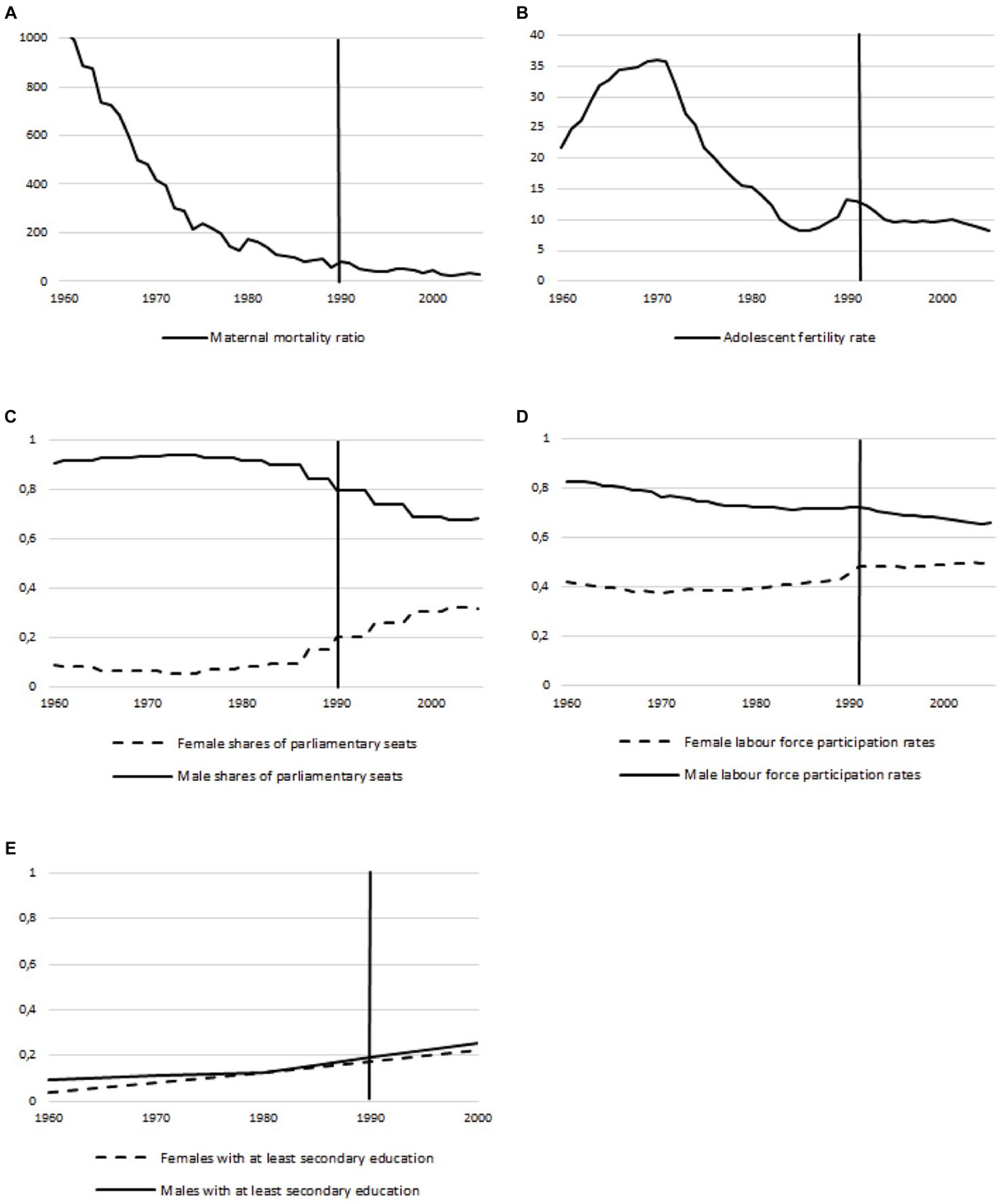

FIGURE 2
Temporal trends of the gender inequality index components from 1960 to 2005 in Germany: **(A)** Maternal mortality rate; **(B)** Adolescent fertility rate; **(C)** Share of parliamentary seats; **(D)** Labour force participation rates; **(E)** Population with at least secondary education. From 1960 to 1990: Former federal territory of Germany, since 1990: The Federal Republic of Germany (FRG).

young men with a low educational status decreases and falls below that of young men with a middle educational status in the last years of the study period, whereas prevalence in young men with a high educational status remained the lowest (Figure 4). The smoking prevalence of young women stratified by education showed that young women with a high level of education had the highest smoking prevalence at the beginning of the study period, before the pattern reversed after 10 years of the study period and the highest smoking prevalence was among young women with a low level of education, followed by middle education and, lastly, highly educated. From 2003

onwards, the smoking prevalence of young women with a low educational status decreases and approaches the smoking prevalence of young women with a middle educational status, whereas prevalence in young women with a high educational status remained largely unchanged (Figure 4; Additional file 3).

Correlation between Gender Inequality Index and gender smoking ratio

The bivariate correlation between the GSR and the GII showed a strong correlation of −0.71 (95% CI: −0.93, −0.15; Additional file 4); indicating that more gender equality correlates with greater equality in the smoking behaviour between young women and men. The greater equality in smoking was due to the fact, that young women's smoking rate approached the rate of male smokers. The strength of the correlation decreases slightly as the level of education decreases [low educational status: $r = -0.69$ (95% CI: −0.92, −0.10); middle educational status: $r = -0.74$ (95% CI: 0.93, −0.20); high educational status: $r = -0.78$ (95% CI: −0.94, −0.29); Additional file 4].

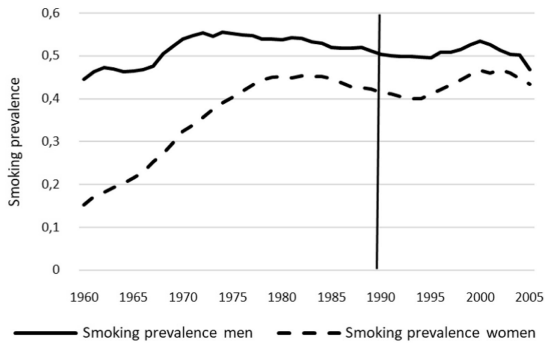

FIGURE 3
Smoking prevalence of young women and men from 1960 to 2005 in Germany.

Discussion

The results of our ecological study illustrate how gender equality in Germany has increased in the period from 1960 to 2005 and in parallel the GSR has decreased. This trend is based on the fact that during the period under study, the prevalence of smoking increased among women while it remained relatively constant among men, which in turn led to a decrease in GSR (Figures 1, 3). Another core finding was that young women and men with a higher educational status smoked less than those with a middle and low educational status. The strong negative correlation between the GSR and the GII shows that more gender equality correlates with greater equality in the smoking behaviour between young women and men in Germany.

According to a 2019 study by the European Institute for Gender Equality, Germany is still below the European Union average in terms of gender equality. Although there has been a slight increase in gender equality since 2015, Germany ranked 12th in comparison to the other European member states in 2019 (38). This is in spite of the fact that the Federal Constitution has prescribed equal rights for men and women in Germany since 1949. The article which defines these rights includes promoting the enforcement of equal rights for women and men as well as efforts to eliminate existing disadvantages by the government (39). Nevertheless, unequal chances for men and women are reflected in unequal social, economic, and political participation and promote discrimination, violent conditions and structural disadvantages due to institutional frameworks. In 2018, new equality policy goals for Germany were published by the Federal Ministry (40).

Our findings of social differences in smoking are in line with similar findings in other European countries (17–20, 35, 41). In the beginning of the 20th century, women rarely smoked because it was socially undesirable or unacceptable. This is reflected in the social value systems of the time and gender-specific defined roles (42–44). The change in smoking behaviour mirrors the social change in gender roles and identities during the 20th century. The emancipation movement over the past 100 years, for example, was accompanied by an increased acceptance of women smoking. The tobacco industry

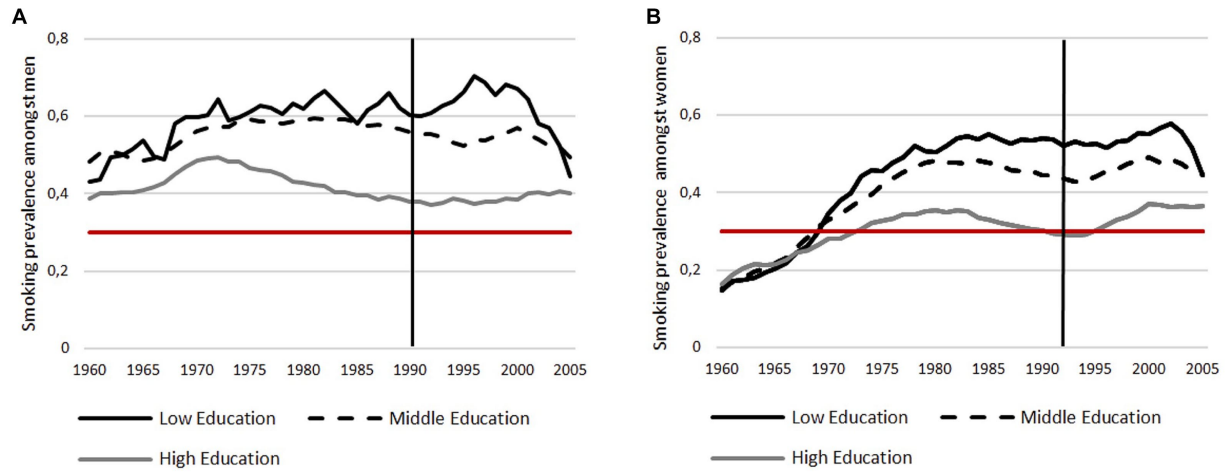

FIGURE 4
Smoking prevalence of men and women stratified by education: **(A)** Smoking prevalence among men; **(B)** Smoking prevalence among women. For better illustration, a reference line with 30% is added.

took advantage of this early on and introduced gender-specific tobacco advertising, using the image of a woman smoking as a sign of emancipation for its marketing campaigns (14, 39). Later, the tobacco industry's advertising campaigns and marketing strategies aimed at young women in privileged circumstances, were shaped not only by notions of independence but also of romance and glamour, leading to a higher prevalence of smoking in this age group (41–44). However, meanwhile, it is particularly noteworthy that in several European countries including Germany, the highest smoking rates are now seen in girls with lower social status (41, 45).

The results of our study confirm that gender equality correlates with greater equality in smoking behaviour between young women and men. The promotion of gender equality in a society should therefore be taken into account from a political perspective when developing anti-smoking messages and counteract the targeted gender-based advertising strategies of the tobacco industry.

The total annual tobacco advertising expenditure has increased in recent years from approximately 193 million Euros in 2008 to 210 million Euros in 2019 (3, 46). Advertising for tobacco products, especially aimed at the target group of young adults, is extremely lucrative, as several studies also show that a quarter to half of young adults who start smoking stick with it and become daily smokers (11, 21, 25). In Germany, the tobacco industry currently still has many possibilities to promote its products. The restrictions on tobacco advertising have been extended since the beginning of 2021. Since then, cinema advertising for tobacco products is only allowed at certain times and for films suitable for 18-year olds and over. From 2022, advertising is only allowed in specialised shops (47). Notwithstanding the fact that the overall gender inequality measured by the GII is significantly higher in Germany than in Spain, a similar trend of an increase in gender equality and a simultaneous decrease in GSR was observed by Bilal and colleagues who examined the relationship between the GII and GSR for the entire Spanish population (35). In contrast to Bilal and colleagues, whose analyses did not focus on a specific age group, we have limited our analysis to the subgroup of 15 to 25-year olds, as this population might have a high potential for smoking prevention. It might be noteworthy, that although the meaning of gender roles may become manifest further in life, the correlation between the GII and the GSR in Germany could also be observed in this age group of young adults.

The GII was developed by the United Nations to compare countries around the world (37). However, it should be noted that the GII includes components, such as maternal mortality, that may not fully capture gender inequality in the industrialised nations, like Germany. In other nations with poorer healthcare, these indicators are more meaningful. As a single indicator, therefore, maternal mortality cannot be considered a valid substitute for the GII. Nevertheless, we have chosen this index to ensure the best possible comparability with other studies worldwide. Particularly with regard to the other individual indicators of the GII, such as the labour force participation rate, the single indicators of the GII can certainly be regarded as valid proxies of the GII. As shown in Figure 2, both access to (higher) education and the number of parliamentary seats held by women in Germany have increased steadily over time. In principle, it is encouraging from a gender equality perspective that the opportunities for greater female labour force participation are steadily improving, but higher labour force participation can also be associated with more work stress in everyday working life, which in turn leads to a higher prevalence of smoking (48), which is also reflected in the gender smoking ratio.

Limitations and strength

Some limitations need to be addressed. As already mentioned, not all GII indicators reflect the GII to the same extent for Germany. Furthermore, reproductive health, is a very important factor in mapping women's health. In contrast, however, no information on men's health status is included in the calculation of the GII. To obtain a comprehensive picture of gender inequality, this would potentially be a relevant factor (42). Furthermore, for the present analyses, it must be considered when interpreting the GII for Germany that from 1960 to 1989 only data for the former federal territory are available, and from 1990 this data is for Germany as a whole. It might have been worthwhile to calculate the GII for the entire period for Germany as a whole or to conduct comparative analyses between GDR and FRG. Due to the different structures and political systems of GDR and FRG, a comparison of these societies especially in relation to aspects of gender inequality might be very insightful. Many discriminatory laws in the GDR were repealed in 1949, much earlier than in the FRG. An example concerning gender inequalities are the different employment rates of women between the GDR and FRG. Female workers were urgently needed in the GDR which resulted in a female employment rate of 45% in 1950 and an increase to over 90% in 1989 (49). However, the household chores were assigned in most cases to women, which led to a double burden and often prohibited career advancement. Additionally, the proportion of female university students was lower than in the FRG (49). Finally, another example is the proportion of female policy-makers in the government which was significantly higher in the GDR than in the FRG. While a quarter of policy-makers were women in the GDR in 1960, the proportion in the FRG was only 9%. In 1989, the proportion of women in the GDR government was 32%, while in the FRG it was approximately 15% (50, 51). However, the proportion of women in the higher, more powerful positions in politics was very low in the GDR (49). Consequently, it could be assumed that if data from the GDR were included, the GII would possibly be lower and there would therefore be less measured gender inequality.

Another limitation concerns the data used for the GSR. The sample of the GEDA study comprises the adult German-speaking population from private households in Germany based on a pool of publicly available telephone numbers from landlines, which means that people without a landline connection are excluded (30–33). This may introduce bias, as people without a landline connection are not captured. However, over 90 percent of households in Germany had a landline connection during the survey period (52). Furthermore, the calculation of smoking prevalence is based on self-reported smoking data. This may be subject to recall or social desirability bias.

In addition, the ecological study design does not allow conclusions to be drawn at the individual level but is limited to analyses at the population level.

To assess temporal trends a period of 45 years was analysed. Strength of our study is the large sample size and high quality of the data, which made it possible to provide valid and representative information about the 15-25-year-old residing in the former federal territory of Germany from 1960 to 1990 and for Germany as a whole

from 1990 to 2005. The methodology used in this paper (by Harris et al.) allows for analyses over a long period of time, which is a strength compared to conventional ecological studies. To the best of our knowledge, it is the first study to show the temporal changes in gender inequality and smoking prevalence of young women and men between 1960 and 2005 in Germany.

Conclusion

This study provides relevant information on the temporal development of smoking prevalence among young adults in Germany. It is the first ecological study to describe differences in smoking behaviour in Germany as a function of educational status over a period of several decades. In terms of monitoring the development of gender equality in a society, gender-specific smoking patterns might be predicted more accurately and tobacco control measures could be adapted accordingly. Experts in gender-sensitive public health research should be involved and consulted in the development of counter-advertising messages and gender-specific information in light of tobacco prevention in young women and men.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

JR: Conceptualization, Methodology, Writing – review & editing, Formal analysis, Project administration, Writing – original draft. GB: Conceptualization, Methodology, Writing – review & editing. BR: Writing – review & editing, Data curation, Formal analysis. RK: Writing – review & editing, Conceptualization, Methodology, Resources. AS: Conceptualization, Methodology, Resources, Writing – review & editing. EM: Conceptualization, Methodology, Writing – review & editing, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1295050/full#supplementary-material

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Tobacco consumption and quality of life among teachers: a bidirectional problem

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Objective: This study aimed to assess a bidirectional relationship between tobacco consumption and quality of life among Chilean teachers.

Participants and methods: A total sample of 647 Chilean teachers was included in a cross-sectional study (71.8% female). Teachers completed a socio-demographic questionnaire, tobacco consumption habits, and the SF-36 questionnaire to assess quality of life. Logistic regression models were employed for statistical analysis of quality of life (physical component summary; mental component summary), and tobacco consumption habits, adjusted for socio-demographic characteristics.

Results: A total of 34.2% of teachers were smokers, with the majority (68.7%) being under 45 years old. Smoking teachers demonstrated lower quality of life scores, particularly mental health and emotional problems dimensions, and mental component summary ($p < 0.05$) versus nonsmoking teachers. Teachers with tobacco consumption had a higher risk of low mental component summary (OR: 1.74; $p < 0.001$), and those with low mental component summary were more likely to be smokers (OR: 1.77; $p < 0.002$).

Conclusion: These findings indicate that tobacco consumption adversely affects the quality of life of Chilean teachers, especially their mental health. Psychological support should be provided to help teachers cope with work stress and tobacco consumption.

KEYWORDS

tobacco use, smokers, quality of life, school teachers, mental health

1 Introduction

There is a broad body of background data to show that teaching is a profession practiced well beyond established pedagogical hours in educational centers. In this sense, teachers continue their jobs within their homes when they perform different job-related activities, such as class planning, reviewing homework, tests and projects, preparing class material, and seeking out new teaching strategies (1, 2). Therefore, work overload among teachers can lead to different afflictions or diseases linked with the physical realm such as voice disorders (3), musculo-skeletal disorders and/or obesity

(1, 4, 5), as well as a deteriorated mental health (6–11), and decreased quality of life (QoL) among teachers (5, 12–15). In this context, the WHO defines quality of life as an individual's perception of their cultural environment and their values concerning specific goals, standards, and expectations. This is coupled with mental and physical well-being, state, level of independence, interpersonal relationships, surroundings, and individual convictions (16). Furthermore, apart from work overload, it has been shown that long working hours and long commutes to educational centers cause QoL problems for teachers (2, 17) as they lack the time to perform other types of activities, such as spending time with their families (2, 13). In Chile, several studies have been carried out on the quality of life of teachers, and a significant deterioration has been observed, mainly among women and young teachers (4, 5, 12, 15).

It has also been reported that a habit used by teachers to reduce their stress levels is TC (18) since it boost energy and reduces anxiety (19). Additionally, a considerable prevalence of CT has been found in younger and female teachers (6, 20). TC is a major cause of death worldwide, with around 7 million people dying annually due to direct TC (21). TC is related with different non-transmissible diseases, including cardiovascular diseases. A large part of the deaths (70%) related with cardiovascular diseases were attributed to modifiable risk factors including TC (22). TC has also been related with different types of cancer, including in the lungs, larynx, mouth, and esophagus, as well as chronic respiratory diseases and diabetes (23). TC has been related with deficient mental and physical health as well (24–27) since TC leads to premature skin aging, tooth loss, and increased gum disease risk, along with making wounds take longer to heal (23). TC can be related with mental illnesses too, since nicotine acts on neurotransmitter pathways, affecting serotonin release, which can cause depression (21). Reports indicate that people presenting some type of mental illness have a higher probability of TC, as it has been observed that an important of the mentally ill population smokes (25, 28–31).

Across Latin America, Chile has the highest rate of TC, reaching 38.7% in 2015, compared to Argentina at 22.6% and Brazil with a 14.3% rate (32). While the National Health Survey (ENS 2016–17) indicated a TC rate of 33.3% (33), this is still a high figure and must be considered. At the gender level, men have a higher TC rate than women (43.4% men, 36.5% women) while in the age group breakdown, the age groups of 20–29 years and 30–49 years have the highest TC rate (41.1 and 41.4%) compared to other groups (33), meaning that Chile has a sustained high TC rate. In this sense, few studies have reported the prevalence of TC in Chilean teachers. Thus, a prevalence between 31.96 and 35.9% has been described in Chilean teachers (6, 20, 34).

TC has been reported as having a negative effect on QoL, as different studies have observed that smokers have a lower QoL compared with nonsmokers (35–39). Additionally, studies on teachers report a strong relationship between mental health and CT. However, there remains a reasonable doubt whether a CT affects the mental health of teachers or whether low teacher mental health increases the risk of CT. Therefore, we set out three objectives for the following research. (1) To describe the prevalence of Chilean teachers who smoke, (2) to evaluate a bidirectional association between tobacco use and mental component of QoL.

2 Materials and methods

2.1 Participants and data collection procedure

The target population of this cross-sectional study consisted of Chilean teachers working in various educational centers belonging to the three national macrozones of Chile: the north, the center, and the south ($N = 249{,}865$) (40). The schools were chosen randomly from 28 schools in three Chilean regions, namely: northern zone: Arica and Parinacota Region (41%); central zone: Valparaíso Region (36%); and southern zone: Araucanía Region (23%). The sample was calculated with 95% confidence and 5% error. To calculate sample size, we selected the variable with the greatest variance for this study group according to extant literature. The sample was determined with Chilean teachers' TC and QoL variables. The minimum sample was 537 participants, where the sample size also rose by 30% in case of possible abandonment. Sampling was done between 2018 and 2019. Thus, the final sample comprised of 647 teachers (71.8% women), 409 have less than 45 years old (63.2%), 316 was married/partnered (48.8%), 407 have not children (64.2%), 407 have a contact in an indefinite-term (64.1%), 366 are teachers in private subsidized schools (56.6%).

All procedures in this study complied with bioethical standards according to the Declaration of Helsinki and were approved by the Ethics Committee of the Pontifical University of Valparaiso, Chile (n°BIOEPUCV-H 160-2017). The research was conducted between 2018–2019.

Before data collection, the establishments chosen randomly from the three macro-zones of Chile were contacted to describe the study's objectives through a face-to-face meeting. Subsequently, each participant had to read and sign an informed consent form inviting voluntary and confidential participation in the study, which did not imply remuneration, compensation, or conflict of interest with the researchers. The inclusion criteria of this research are that the teachers are working in the classroom. Therefore, teachers who performed administrative tasks were excluded. The teachers completed the questionnaires in person and on paper. All the evaluations were carried out in the same educational establishments.

2.2 Instruments

The sociodemographic data of the teachers in this study were gathered via surveys, where the docents themselves provided information about their age, gender, marital status, number of children, work contract types (fixed-term or indefinite) and the type of school where they worked (public, charter school, or private school).

To evaluate teachers' QoL, we used the SF-36 questionnaire, in the version validated for use in Chile (12, 41), since the SF-36 survey was originally created and standardized for the USA (42, 43). In addition, the SF-36 questionnaire has been validated for Chilean teachers (12), as it is widely used in them (4, 5, 15). The SF-36 questionnaire evaluates participants' QoL via 36 Likert-type questions grouped into eight scales: physical function (PF), physical role (PR), body pain (BP), general health perception (GH), vitality (V), social function (SF), emotional role (ER), and mental health (MH). These eight

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dimensions are grouped into two summary measurements: The Physical Component Summary (PCS) as the first component, and the Mental Component Summary (MCS) as the second. The scores obtained from each scale and component were transformed into a scale from 0 to 100, which will be standardized calculating a T-score value for each scale and PCS and MCS measurement (43). When the T-Score values are above 50, they indicate a good QoL perception, while T-Score values below 50 indicate poor QoL perception. Considering the internal consistency of the SF-36 scale, the Cronbach's Alpha coefficient was $\alpha \geq 0.85$ for each of the eight variables.

To evaluate teachers' TC, we used a tobacco addiction questionnaire with simple questions classifying participants into different TC categories (6).

For our purposes, anyone who met the following criteria was considered a smoker:

- Occasional smoker: someone who smokes less than one cigarette per day.
- Daily smoker: someone who has smoked at least one cigarette per day in the last 6 months.

Teachers who responded affirmatively to the questions were classified as "smokers," and those who responded negatively were classified as "nonsmokers."

2.3 Statistical analyses

Data analysis was done with STATA 16 software for Windows. For the associations done between the categorical variables, we used Fisher's exact test and the χ^2 test. The participants' age was classified into two categories ($\leq$44 years and $\geq$ 45 yrs) according to the cutoff scores in the Chilean National Health Survey of 2009–2010 (44). Sociodemographic variables were evaluated between the various TC categories (non-smoker, ex-smoker, and smoker) using the χ^2 test. We applied an ANOVA as well to evaluate the differences between the 8 QoL dimensions regarding the different TC categories, followed by a post-hoc test (Bonferroni). Two logistic regression models were done after this, the first of which was a logistic regression using the PCS and MCS from QoL (for this dichotomous variable the cut-off point was the t-score at 50 of QoL) as a dependent variable to evaluate the association with TC (smokers). The second logistic regression used tobacco-consuming teachers (smokers) as a dependent variable to evaluate whether smoking teachers tended to present lower PCS and MCS scores due to TC. The aforementioned regression models were adjusted for the gender and age covariables (gender and age variables have been selected because previous reports have identified differences in these variables in Chilean teachers) (6, 20), and the goodness of fit used for each logistic regression model was demonstrated with a Hosmer-Lemeshow test.

3 Results

Table 1 presents the sociodemographic characteristics analyzed by participants' gender. A total of 647 teachers were analyzed of which 465 were women (71.8%) and 182 were men (28.1%). 63.2% of participants were in the first age category (<45 years). There is a significant association between marital status and participants' gender ($p < 0.005$), with a higher rate among the category for men with a spouse or partner, reaching 53.8%. No significant association was observed between gender and age, having any children, work contract type, and the type of school where the participants worked.

TABLE 1 Teachers' sociodemographic characteristics by gender.

	Total (*n* 647)		Male (*n* 182)		Female (*n* 465)		
Variables	*n*	%	*n*	%	*n*	%	*p* value[a]
Age (years)							
<45	409	63.21	115	63.19	294	63.23	0.993
>45	238	36.79	67	36.81	171	36.77	
Civil status							
Single	275	42.50	78	42.86	197	42.37	
Married/partnered	316	48.84	98	53.85	218	46.88	0.008
DWW*	56	8.66	6	3.30	50	10.75	
Children							
Have	227	35.80	70	40.00	157	34.20	0.174
Have not	407	64.20	105	60.00	302	65.80	
Type of contract							
Fixed-term	228	35.91	55	31.07	173	37.77	0.115
Indefinite-term	407	64.09	122	68.93	285	62.23	
Type of school							
Public (state)	220	34.00	54	29.67	166	35.70	0.145
Private (subsidized)	366	56.57	114	62.64	252	54.19	
Private (non-subsidized)	61	9.43	14	7.69	47	10.11	

[a]Chi-squared test. $p < 0.05$.
DWW, divorced/widow/widower*.

The association between sociodemographic characteristics and MSD with teachers' QoL appears in Table 2. The PHC on QoL has a significant association with the p50 of MSD ($p = 0.023$). On the other hand, in the MHC of QoL, there are significant associations in age, contract type, and p50 category ($p < 0.01$). Significant associations allow us to observe that most teachers below the T-Score for MHC are those age 44 or less and indicating that they had 6 or more body regions with MSD. Teachers with indefinite work contracts also had better mental health (87%).

Table 2 shows participants in different TC categories (non-smoker, ex-smoker, and smoker), analyzed against the participants' sociodemographic traits. We observed a significant association between the participants from the first age category of <45 yrs. and the smoker-type TC category (68.7%, $p < 0.05$).

Table 3 compares the scores from each of the eight dimensions and the two summary measurements from the SF-36 QoL survey, analyzed with each participant TC category. The results showed significant differences between the role limitations dimensions due to emotional problems, mental health and on the MCS measurement ($p < 0.05$), observing that smoking teachers had a lower score on the aforementioned dimensions than non-smoking participants.

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TABLE 2 Teachers' sociodemographic traits analyzed by tobacco consumption category.

	Total (*n* 647)		No smokers (*n* 359)		Ex-smokers (*n* 67)		Smokers (*n* 221)		
Characteristics	*n*	%	*n*	%	*n*	%	*n*	%	*p* value[a]
Gender									
Male	182	28.13	100	27.86	24	35.82	58	26.24	0.307
Female	465	71.87	259	72.14	43	64.18	163	73.76	
Age (years)									
<45	409	63.21	222	61.84	35	52.24	152	68.78	0.035
>45	238	36.79	137	38.16	32	47.76	69	31.22	
Civil status									
Single	275	42.50	152	42.34	19	28.36	104	47.06	
Married/partnered	316	48.84	174	48.47	40	59.70	102	46.15	0.090
DWW*	56	8.66	33	9.19	8	11.94	15	6.79	
Children									
Have	227	35.80	127	35.67	17	26.15	83	38.97	0.168
Have not	407	64.20	229	64.33	48	73.85	130	61.03	
Type of contract									
Fixed-term	228	35.91	128	36.47	22	32.84	78	35.94	0.851
Indefinite-term	407	64.09	223	63.53	45	67.16	139	64.06	
Type of school									
Public (state)	220	34.00	118	32.87	21	31.34	81	36.65	
Private (subsidized)	366	56.57	209	58.22	39	58.21	118	53.39	0.814
Private (non-subsidized)	61	9.43	32	8.91	7	10.45	22	9.95	

DWW, Divorced/Widow/Widower*.
[a]Chi-squared test. $p < 0.05$.

TABLE 3 Comparison of eight QoL scales and summary measurements by TC categories.

Quality of life (QoL)	No smokers (a)	Exsmokers (b)	Smokers (c)		
Dimensions	Mean-SD	Mean-SD	Mean-SD	*p* value[a]	Post hoc[b]
Physical function	51.42 ± 6.58	51.55 ± 7.11	51.39 ± 7.15	0.986	–
Physical problems*	49.94 ± 5.68	51.03 ± 5.37	49.77 ± 6.11	0.286	–
Bodily pain	45.05 ± 9.87	45.40 ± 9.13	43.92 ± 9.41	0.322	–
General health perceptions	47.79 ± 9.80	47.53 ± 8.71	46.15 ± 10.08	0.141	–
Vitality	48.84 ± 9.11	48.77 ± 8.20	47.31 ± 8.36	0.116	–
Social functioning	44.21 ± 10.52	45.24 ± 9.75	42.77 ± 10.98	0.146	–
Emotional problems**	49.11 ± 6.54	49.22 ± 5.91	47.70 ± 6.82	0.034	a > c
Mental health	47.79 ± 9.86	47.51 ± 10.14	45.51 ± 10.22	0.027	a > c
PCS	49.13 ± 6.47	49.64 ± 6.03	49.03 ± 6.51	0.788	
MCS	46.90 ± 9.65	46.88 ± 9.76	44.61 ± 10.07	0.019	a > c

[a]Chi-Squared. $p < 0.05$.
[b]ANOVA with post hoc comparison using Bonferroni test.Differences group details (columns a,b, and c). Role limitations due to physical problems *. Role limitations due to emotional problems **. PCS, Physical Component Summary; MCS, Mental Component Summary. The data are presented in T-scores; scores above 50 indicate good QoL perception, while scores below 50 indicate poor QoL perception.

Table 4 is a logistic regression model, evaluating the association between the QoL summary measurements (PCS and MCS; low PCS and MCS are values under 50) and TC (smokers). Smoking teachers have a higher risk of low MCS scores (OR: 1.74; $p < 0.05$). Teachers who were < 45 years old presented a greater risk of significantly lower PCS scores (OR: 1.86; $p < 0.01$), while for teachers <45 yrs. age granted a protective factor, as they had a lower risk of low MCS scores (OR: 0.56; $p < 0.01$).

TABLE 4 Logistic regression model to evaluate the association between the PCS and MCS for QoL regarding TC (smokers), adjusted by gender and age.

	PCS (50th percentile)		MCS (50th percentile)	
	OR [95% CI]*	*p* value	OR [95% CI]*	*p* value
Tobacco consumption (smokers)	0.96 [0.68–1.33]	0.795	1.74 [1.23–2.47]	0.002
Gender	1.36 [0.96–1.93]	0.082	1.29 [0.90–1.83]	0.161
Age (<45 years)	1.86 [1.34–2.58]	0.000	0.56 [0.40–0.77]	0.000
Hosmer–Lemeshow Test[a]	0.299		0.822	

PCS, Physical Component Summary; MCS, Mental Component Summary. *OR [95% CI], Odds Ratios [95% confidence interval].
[a]A value above 0.05 indicates the goodness of fit of the models are satisfactory.

TABLE 5 Logistic regression to evaluate the association between TC (smoking) with the QoL summary measurements (PCS and MCS) adjusted for gender and age.

	Tobacco consumption (smokers)		
	OR [95% CI]	SE	*p* value
PCS[a]	0.89 [0.63–1.24]	0.32	0.481
MCS[b]	1.77 [1.25–2.52]	0.15	0.001
Gender	1.13 [0 0.78–1.63]	0.21	0.527
Age	0.76 [0.53–1.09]	0.14	0.131
Hosmer–Lemeshow test[c]	0.620		

[a]PCS, Physical Component Summary.
[b]MCS, Mental Component Summary; OR, Odds Ratios [confidence interval]; SE, Standard Error.
[c]A value above 0.05 indicates that the model fits the data.

Table 5 contains a logistic regression with the TC category (smokers) as a dependent variable, and QoL adjusted by gender and age. Teachers with low MCS scores for QoL had a higher risk of being smokers (OR: 1.77; $p < 0.01$). This model also shows that the TC risk factor is independent of participants' age and gender.

4 Discussion

The main results show that TC prevalence among teachers considered in this study was 34.2%. This is lower than other studies, such as one from 2003 where the TC rate among Chilean teachers reached 35.9% (34). The decreasing TC rate appears not only among teachers, but also across Chile, falling from 39.8% in the 2009–2010 National Health Survey (ENS), to 32.5% in the 2016–2017 (33, 44). Across South America, Chile has one of the highest TC rates compared with other countries, such as Argentina at 22.5% and Colombia with 9.5% (19). However, in other countries, TC among teachers is notably lower than in Chile. TC among Turkish teachers stood at 20.1%22, while in Botswana it was only 3.2% (45).

The age of teachers in the sample mainly fell into the first age category, i.e., between 25 and 44 years old (63.21%) (Tables 1, 2). These data align with those reported by the Education Ministry in the 2020 teachers' variation, which reported that 62.9% of teachers recorded in the Chilean school system fell within the <45 year age range (10). Our results also indicate a significant association between TC and teachers being <45 years old ($p < 0.05$). These results are similar to the data from the 2016–2017 ENS, where participants from the 25–44 year age group had a higher TC rate (33). Young teachers have been reported as being exposed to different problems related with teaching work, such as job instability, a situation which negatively impacts young teachers' mental health given its concomitant financial uncertainty (11). We should add that young teachers are more likely to have negative mental health impacts as well since they have high anxiety and depression rates (6, 10) which could be related with the aforementioned problems.

It is widely documented that smokers tend to have a lower QoL than nonsmokers (36–38). With regards to our results, we can observe that smoking teachers tend to score lower on the role limitation dimensions due to emotional problems, mental health, and on the MCS measurement ($p < 0.05$). We also reported that teachers who smoke have a higher risk of lower MCS scores (OR: 1.74; $p < 0.02$) and that those with a low MCS score for QoL have a higher risk of being smokers (OR: 1.77; $p < 0.01$); we can thus indicate that TC can be related with mental health problems among Chilean teachers. These findings mesh with prior studies indicating that many people with mental health problems or diseases are smokers (25, 28, 29) and that TC also doubles of probability of suffering mental health issues (46).

The physical and mental health problems associated with TC in the smoking population are a widely documented situation, but they still cause alarm. Reports show that smokers who consume 1 to 3 cigarettes per day are 3 times likelier to die from lung or heart disease (26) and that having 1 to 4 cigarettes per day is associated with doubling smokers' mortality risks, compared with nonsmokers (27). Yusuf et al. (22) reported that around 70% of deaths related with cardiovascular disease in middle-income countries, which includes Chile, were attributed to modifiable risk factors including TC. This shows the odds of improving smokers' QoL if they quit smoking, as they would avoid generating TC-related cardiovascular diseases. It is noted that quitting smoking improves QoL (19, 24, 25) and that behavioral interventions involving both physical activity and quitting smoking simultaneously improve QoL better than only doing one of these interventions at once. Nduaguba et al. noted that ex-smokers who did physical activity had between 70 and 160% better odds of presenting higher QoL than ex-smokers who did no physical activity (39). In this sense, the relationship between TC and mental health is influenced by various factors ranging from nicotine addiction to social and environmental determinants. In that sense, addiction to nicotine, one of the main components of tobacco, has been reported to exacerbate or contribute to the development of mental health problems (29). TC can cause changes in the nervous system and interactions with psychiatric medications, complicating existing mental treatments and having critical effects on people's QoL (30). In addition, it has been observed that people with mental problems present a high prevalence of TC (28). In this sense, teachers who are exposed to greater factors that may affect their mental health could suggest a bidirectional influence, in which mental health problems may increase tobacco use. Tobacco use, in turn, may exacerbate mental

health conditions (31). In this context, it has been observed that in a bidirectional manner, teachers with high emotional exhaustion consume more tobacco, and conversely, teachers with high TC also present a higher risk of emotional exhaustion (6). Therefore, the evidence shows that health strategies in teachers cannot be treated as individual factors but must be addressed in a comprehensive manner.

The teaching profession has one of the highest workloads, as the work continues beyond the classroom, leading to physical and mental health problems for teachers (1, 7, 10, 12). When comparing teaching with other professions regarding engagement and work exhaustion, we observed that teachers had lower engagement and higher exhaustion than other professionals (8). It is thus important to apply methods and strategies to help teachers with their mental health (9) and TC (47). In this sense, the social environment and support systems are essential in TC and cessation. The presence of a supportive social network can facilitate smoking cessation efforts, whereas a lack of support can hinder them. In addition, social cues and reinforcement of smoking behavior through peer networks and the media can influence smoking (48, 49). Therefore, initiatives involving smoke-free (TC-free) environments within educational establishments involving teachers could be an opportunity to improve self-care and prevent TC-associated risks in teachers. In this sense, Chile has national plans involving the entire educational community to prevent TC (50). In the coming years, there should be an evaluation of the policies applied. In addition, intervention strategies aimed at teachers could be applied (47). However, interventions in teachers should be more comprehensive because the evidence in this work shows that the factors cannot be treated in isolation.

5 Limitations

The present study has various limitations which must be considered. The first limitation is common to all cross-sectional studies, in that it provides a momentary snapshot of the teachers involved and does not allow us to carry out a cause-effect relation. The second limitation was the study sample. While the teacher sample was representative, as it covered the three national macrozones of Chile (north, center, and south), this only provides a general nationwide vision of teachers' TC and QoL. The third limitation is that the data obtained for the study were gathered before the COVID-19 pandemic, which has negatively impacted teachers' QoL due to lockdowns and the fact of adjusting to a reality which has affected both their mental and physical health (10–13). Therefore, if a study similar to ours was done today after the height of the pandemic, it is likely that QoL values would be lower, and TC would be higher.

6 Conclusion

The objective of this study was to analyze TC among Chilean teachers and observe the effects of TC on teachers' QoL. The present study reported that approximately one-third of the school teachers TC. In addition, we observed that TC negatively affects Chilean teachers' QoL, as we can observe lower scores in various QoL dimensions including mental health and role limitations due to emotional problems, along with MCS among teachers who smoke. We reported a bilateral association between MCS and TC where teachers with TC had a higher risk of low MCS while teachers with low MCS also had a greater risk of smoking. Our results thus describe a negative effect of TC on QoL. Programs and public policies should be implemented to help teachers quit smoking, by showing the benefits which arise once they quit, along with reducing the risk factors which affect teachers' mental health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee at Pontificia Universidad de Valparaíso, Chile (n°BIOEPUCV-H 160-2017). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

PL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. VV-G: Investigation, Writing – original draft, Writing – review & editing. LB: Investigation, Writing – original draft, Writing – review & editing. LL: Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Identifying factors influencing local governments' adoption of comprehensive smoke-free policies: an event history analysis based on panel data from 36 key cities in China (2013–2021)

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Introduction: The issue of tobacco control remains a significant concern for public health worldwide. In recent years, remarkable progress has been made toward adopting smoke-free measures in indoor public places. Although China has yet to introduce a national regulation, specifically for smoke-free public places, more than a dozen cities have successively approved and implemented comprehensive smoke-free regulations. Different cities in China have diverse attitudes and behaviors toward smoke-free policies; however, the reasons for these policy differences and the influencing factors have not received sufficient attention and research.

Methods: On the basis of the multiple streams framework, this study selects 36 key Chinese cities as research samples and uses a directed dyad-year event history analysis method to analyze the factors influencing the implementation of comprehensive smoke-free policies in cities.

Results: Results show that the adoption of such policies is positively influenced by scientific evidence, focal events, media coverage, institutional foundations, economic comparisons, and the influence of health departments and of tobacco control groups. By contrast, policy adoption is negatively affected by the differences in administrative levels, central policy signals, and the influence of the tobacco industry.

Discussion: This study contributes to understanding the internal logic behind local governments' adoption of comprehensive smoke-free policies, offering insights for further advocacy at the city and national levels in China and providing experiences that can promote the global tobacco control movement.

KEYWORDS

tobacco control, smoke-free policy, policy adoption, event history analysis, influencing factors

1 Introduction

Tobacco control is a global public health issue of great concern. Promoting smoke-free measures in indoor public places is one of the core tobacco control strategies continuously advocated by the World Health Organization's (WHO's) Framework Convention on Tobacco Control (FCTC). To date, 74 countries have implemented policies that completely ban smoking

in indoor public places, workplaces, and public transport, up from only 10 in 2007 and covering 2.1 billion people (1). As the largest tobacco producer and consumer in the world, the issue of smoking in public places in China is not optimistic, with approximately 740 million non-smokers suffering from secondhand smoke exposure (2), and a secondhand smoke exposure rate among non-smokers of 68.1%, leading to over 100,000 deaths annually (3). Despite joining the FCTC many years ago, China still does not have a national law that prohibits smoking in public places. With national legislation in a deadlock, tobacco control advocates have turned to local governments for breakthroughs. In recent years, a few cities in China have introduced smoke-free legislation, meeting the WHO's best-practice requirements for a comprehensive smoke-free policy.

Public policy is the most effective way to address the tobacco epidemic (4). The case of China shows that different cities have diverse attitudes and behaviors toward smoke-free policies. Thus, what causes these differences in policies among cities? What factors influence the performance of cities in adopting smoke-free policies in public places? Previous public health research on this topic has mostly focused on the analysis of secondhand smoke exposure monitoring data (5), and the analysis of policies has mainly been the evaluation of the effects of policy implementation (6), lacking an explanation from the perspective of policy formation as to why different administrative authorities have variations in the adoption of tobacco control policies.

The field of tobacco control policy serves as a critical domain for generating theoretical knowledge about the policy process, contributing rich and in-depth empirical material on policy diffusion, policy learning, policy beliefs, and other research topics (7). Research in this area involves a number of countries and regions, including developed countries, such as the United States, Canada, Japan, and Australia (8–10), as well as developing countries, such as Uruguay, Indonesia, Nigeria, and Bangladesh (11–13). As a nation severely affected by tobacco use, the issue of tobacco control in China has also attracted the attention of scholars. Scholars have conducted extensive and in-depth research on smoking behavior at both the micro level of individuals (14) and the meso level of groups (15), providing many insightful ideas for reducing tobacco harm. However, few scholars have focused on the impact of government actions on tobacco control at the macro level. The strategies and experiences of Chinese policymakers in formulating tobacco control policies have not received enough attention from public health advocates and public policy researchers.

Therefore, this study attempts to introduce the perspective of public policy process theory to conduct an in-depth analysis of the factors influencing local governments' enactment of comprehensive smoke-free policies. The primary question it aims to address is: What factors have influenced the adoption of smoke-free policies by local governments in China, and how?

Utilizing the multiple streams framework as its theoretical foundation, this study considers the characteristics of China's political and administrative structures. It adapts and extends the framework to suit the specific circumstances surrounding China's local tobacco control policies, thereby creating an analytical framework to explore what influences local governments to implement comprehensive smoke-free policies and formulating relevant hypotheses accordingly. Furthermore, this study tests the proposed hypotheses using the directed dyad-year event history analysis (EHA) method. Panel data are collected from 36 key cities in China's provincial capitals and above from 2013 to 2021. Using these data, regression analyses are conducted to analyze the factors influencing the adoption of comprehensive smoke-free policies in cities using a discrete-time logit model.

Since 2016, with the official adoption of the "Healthy China" national strategy, China has emphasized the formulation of public policies that embody health-centric principles as an important way to realizing this national strategy (16). In this study, a representative health policy, the comprehensive smoke-free policy, is selected, and the factors influencing the implementation of the policy are analyzed. Results of the study will be useful for the promotion of tobacco control in China, as well as globally. The study also provides some guidance on how to improve the level and quality of social policy, especially health policy formulation. It also has a positive effect on improving the level and capacity of local government governance.

2 Literature review and analytical framework

In addressing global public health challenges, the issue of tobacco control has attracted extensive attention from scholars across different fields worldwide. Overall, research on the adoption of smoking control policies has generally reached the following consensus. First, it emphasizes the contextuality of policy formulation. Smoking behavior is influenced by a complex interplay of historical, social, cultural, psychological, and physiological factors, and the design of tobacco control programs needs to consider social and cultural contexts (17). Second, increasing attention has been paid to the structural socioeconomic and political factors behind the tobacco epidemic (18). In recent years, the effects of political factors on the adoption of public health policies have been particularly emphasized. For example, studies have found that community coalitions can form under various sociopolitical contexts, thereby promoting cooperation among multiple departments of local governments and facilitating the adoption of public health policies (19). Third, the interaction among various policy actors and their effects on policies have garnered considerable interest. For example, scholars have highlighted the role of the media, as well as local and international tobacco control groups, in influencing Japan's tobacco control policies (20). By contrast, the tobacco industry has been particularly dominant in some small island developing countries (11). These studies have provided insightful research perspectives and analytical frameworks for examining the adoption of tobacco control policies in China. However, given the uniqueness of political and administrative systems, the analysis of China's tobacco control policies requires an inclusive theoretical framework and elements of interpretation based on the Chinese context.

This study applies the multiple streams framework as its theoretical basis. As a classic theoretical framework for the public policy formulation process, this framework boasts significant explanatory power and applicability over the past few decades (21). In terms of application areas, the framework has been used for policy process analysis in more than 20 fields, including health, environment, governance, education, and welfare, involving levels such as international, national, and local policies across more than 60 countries with different political backgrounds (22). The multiple

streams framework proposes that public policy occurs in a field full of ambiguity, contingency, and uncertainty, where the policy agenda and alternatives are the result of the combined action of problem, policy, and political streams (23). On the basis of this framework, this study constructs an analytical framework tailored to the specific context of China's tobacco control policy (see Figure 1), proposes corresponding hypotheses, and tests them in subsequent empirical analyses.

2.1 Problem stream-related hypotheses

The problem stream refers to how problems are recognized and defined, and significant events or crises, indicators, and feedback all potentially trigger policymakers' attention to problems. Currently, tobacco control has yet to become a central task for governments at all levels in China (24); thus, the space for tobacco control policies to enter the decision-making agenda of local governments is extremely limited. Local governments' attention to tobacco control in public places comes from three main sources: scientific evidence, focal events, and news reports.

First, scientific evidence is one of the core pieces commonly used in public health (25). Internationally, the ever-emerging scientific evidence demonstrating the strong association between smoking (including passive smoking) and diseases has led to the recognition of tobacco control as a public health issue by governments, which, in turn, have introduced strict policy measures to intervene and control smoking behavior (26). Therefore, local government policymakers, when presented with ample scientific evidence related to smoking and health issues in their region, are more likely to focus on tobacco control issues and thus formulate corresponding policies. Second, events are an important factor in the study of the public policy process, including sudden, unexpected events and planned, foreseeable ones (27). The practice of tobacco control in China shows that when a specific city plans to host major international activities, such as sporting events or exhibitions, it will bring a valuable policy window for tobacco control policies in public places. Local governments are more likely to consider the effects of public place smoking policies on the city's international image during this period (28). Lastly, agenda setting is considered a key link in the formation of public policy, and the mainstream media, by reporting on existing issues, influence decision makers' perceptions of the importance or severity of problems. In this sense, "deciding which issues will become policy issues is even more important than deciding which will become solutions" (29).

Accordingly, three hypotheses related to the problem stream are proposed:

> *H1*: Cities with more comprehensive scientific evidence are more likely to introduce comprehensive smoke-free environment policies.
>
> *H2*: City governments in the period of major international activities are more likely to introduce comprehensive smoke-free environment policies.
>
> *H3*: Cities with more media reports on tobacco control are more likely to introduce comprehensive smoke-free environment policies.

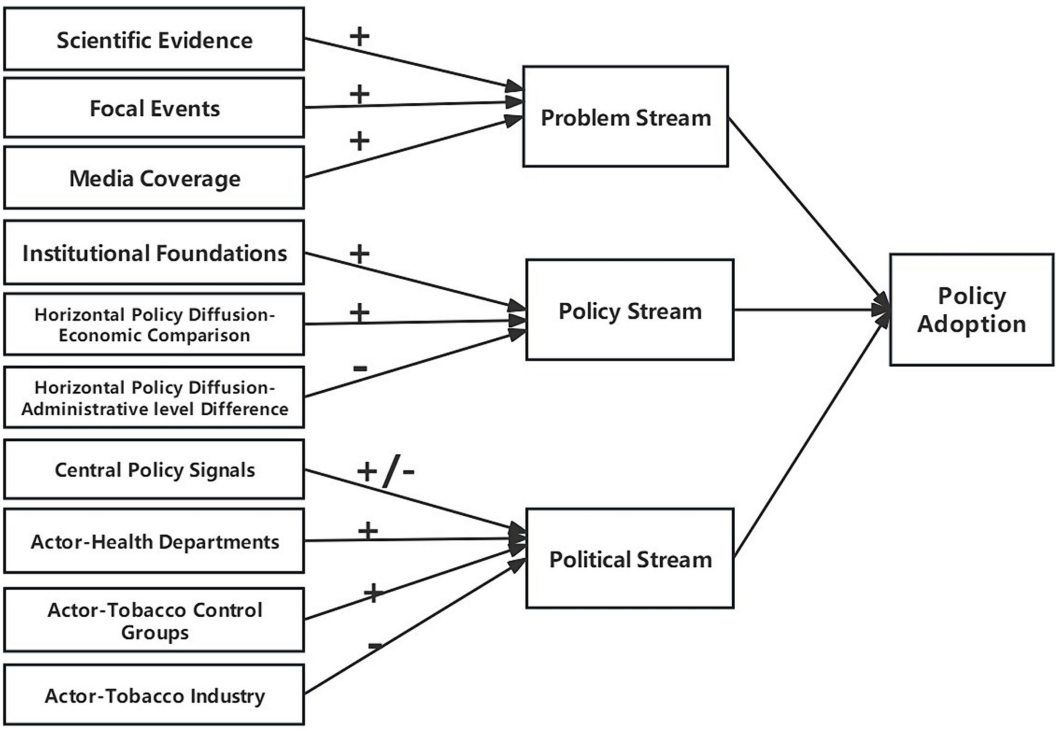

FIGURE 1
Analytical framework for factors influencing local governments' adoption of comprehensive smoke-free policies.

2.2 Policy stream-related hypotheses

The policy stream refers to the process through which policy proposals or advocacies are proposed. For policymakers, judgment on proposals comes partly from internal existing practices, that is, the existing institutional foundation, and partly from the experiences of practices in other areas, namely, the influence of horizontal policy diffusion.

First, for local governments, adopting an innovative policy is a risky act, and adopting a policy with a certain institutional basis or better policy compatibility can reduce the potential political, economic, and social risks after policy implementation. The stronger the policy compatibility is, the higher the likelihood of the government adopting that policy will be (30). For example, the more tobacco control policies a local government has issued, the stronger the compatibility of a comprehensive smoke-free policy with existing policies in terms of ideology and action, and the higher the likelihood of it being adopted. Second, in addition to the internal policy community, the actions of external policy communities in other regions or countries also influence the government's evaluation or judgment of the policy stream (31). When a policy is successfully adopted in a certain region, indicating that the policy stream is mature, other areas are more likely to learn or imitate it. Previous research has shown that governments with higher levels of economic development often have better governance levels and policy performance, serving as a model for other regions (32). Third, local governments, when facing uncertainty of outcomes and complexity of the environment, tend to imitate peer governments with similar circumstances (33). Therefore, this study considers the level of economic development and city level as the main influencing variables for the horizontal diffusion of policies.

Accordingly, three hypotheses related to the policy stream are proposed:

> *H4*: Cities with a greater number of existing smoking control policies are more likely to introduce comprehensive smoke-free environment policies.
>
> *H5*: The likelihood of a city implementing a comprehensive smoke-free policy increases after economically more developed cities adopt such policies.
>
> *H6*: The likelihood of a city adopting a comprehensive smoke-free policy increases after other cities with a similar administrative level implement such policies.

2.3 Political stream-related hypotheses

The political stream refers to the political and cultural context that influences the agenda or outcomes, including public sentiment, competition among interest groups, election results, political party ideologies, and changes in government. For local governments in China, on the one hand, policy signals from the central government constitute an important political context for decision making; on the other hand, distinguishing the competition among interest groups into different actors is more fitting.

As noted earlier, the attention resources allocated by the Chinese central government to the tobacco control subsystem are relatively limited, without the presence of hard compulsory pressure. However, the central government continues to advocate by releasing positive policy signals, such as issuing guidelines and planning outlines related to the field of tobacco control. When local city governments observe continuous positive tobacco control policy signals from the central government, they are more likely to introduce stricter comprehensive smoke-free policies to express their support for the central government. Research has also shown that there might be a more complex relationship between central policy signals and local government actions (34). When the central government has already clearly sent policy signals, local government's policy adoption might lose a degree of innovation and pioneering spirit, thereby weakening the local government's motivation to adopt policies.

This condition leads to two competing hypotheses about central policy signaling:

> *H7a*: The stronger the central policy signals is, the higher the likelihood of cities introducing comprehensive smoke-free environment policies will be.
>
> *H7b*: The weaker the central policy signals is, the higher the likelihood of cities introducing comprehensive smoke-free environment policies will be.

Interactions among specific actors in a particular field are more important for understanding policy change than macro factors, such as economic development and social movements (35). The influence of different actors on policy varies significantly. The three main core actors that influence tobacco control policy at the local level in China are the health departments, tobacco control groups, and the tobacco industry. First, health departments are the primary responsible departments for tobacco control work, participating throughout and regularly in tobacco control policy issues, influencing all stages of policy development. Second, tobacco control groups refer to social organizations involved in advocating tobacco control policies, including Chinese grassroots and international tobacco control organizations. Notably, China's tobacco control process is deeply influenced by international tobacco control organizations. Particularly, the technical support and financial assistance received from international tobacco control organizations since the 1980s has had a profound influence on China's tobacco control progress. Third, the obstruction of the tobacco control process by the tobacco industry is a common occurrence in all countries worldwide (36). The tobacco monopoly system implemented in China endows the tobacco industry with the dual identity of government manager and industry owner, making it the core actor hindering the tobacco control process. The tobacco industry exerts policy influence by providing financial resources to local governments. The more financial resources the tobacco industry supplies to a city, the greater its influence, and the lower the likelihood of the government adopting strict tobacco control policies.

Thus, three research hypotheses regarding actors are proposed:

H8: The greater the influence of health departments is, the higher the likelihood of cities introducing comprehensive smoke-free environment policies will be.

H9: The greater the influence of tobacco control groups is, the higher the likelihood of cities introducing comprehensive smoke-free environment policies will be.

H10: The greater the influence of the tobacco industry is, the lower the likelihood of cities introducing comprehensive smoke-free environment policies will be.

3 Methods

3.1 Sample selection

The adoption of comprehensive smoke-free policies in China demonstrates a distinctive "local initiative" characteristic (37). Currently, a nationwide comprehensive smoke-free policy has yet to be implemented, whereas at the local level, some cities have already achieved the comprehensive smoke-free regulations stipulated by the WHO. Given that the tobacco control performance of provincial capitals and above has an exemplary effect on the region and even the whole country and that they have local legislative power to introduce local tobacco control laws and regulations, this study selects 36 cities, including provincial capitals and above, as research samples. This specifically includes 4 municipalities directly under the central government, 5 subprovincial cities, and 27 provincial capitals.

3.2 Statistical methods

This study employs the directed dyad-year EHA method to analyze panel data of 36 key cities. EHA, also known as survival analysis, is highly applicable for exploring the factors influencing the probability of an event's occurrence and has become a mainstream analytical method in policy innovation diffusion research (38). In recent years, the directed dyad-year EHA has gradually replaced the traditional EHA method and has gained increasing attention and applications (39). The directed dyad-year EHA can provide further insights into the micro-diffusion mechanism among different subjects and deepen policy diffusion research (40). Accordingly, this study uses the directed dyad-year EHA to investigate the diffusion of comprehensive smoke-free environment policies across 36 key cities. The research conducts regression analysis on the factors influencing the introduction of comprehensive smoke-free policies in cities using the discrete-time logit model through Stata 16.0 statistical software.

3.3 Measurement and data sources

The data collected for this study spans from 2013 to 2021, covering the panel data of 36 cities from the introduction of the first city-wide comprehensive smoke-free policy in Qingdao in 2013 until 2021. Policy data primarily comes from the Chinese Laws and Regulations Database (BEIDA FABAO), which is one of the most comprehensive legal databases in China. Other variable data are mainly from the official statistical yearbooks of the cities and the national industry-specific yearbooks.

According to the coding rules of directed dyad-year EHA (41), this method assumes a sequential order of policy diffusion among regions, where i represents the potential policy adopter or learner; and j is the potential policy pioneer or learner, who has adopted the policy earlier than i. The dependent variable *policy adoption* is a binary dummy variable. When city i is paired with city j, if city i adopts a comprehensive smoke-free policy in year t, and city j had already adopted the policy in year $t-1$ or earlier, then the policy adoption (pairing) for city i in year t is valued at 1, otherwise it is 0. After city i adopts a comprehensive smoke-free environment policy in year t, its observations from year $t+1$ onwards are excluded; thus, the sample is subject to right-censoring. Through pairing, an unbalanced panel data set is formed, with the number of pairings or observations being 1,575.

Table 1 presents the detailed descriptions and measurement methods of the variables. The study uses economically relevant indicators to measure the influence of the health sector and the tobacco industry within the government system, that is, the share of health and wellness expenditures as a percentage of the city's general fund expenditures and the share of taxes paid by the city's tobacco industry as a percentage of the city's total tax revenues. Previous empirical research on the diffusion of tobacco control policy innovations has shown that local governments with a high share of health and wellness fiscal expenditures are likely to adopt restrictive smoking policies to reduce tobacco-related healthcare costs (42). In addition, the nature of the government's allocation of public funds is the government's goal orientation and power structure (43). Although the tobacco industry's contribution to local finances is considered to be the fundamental reason for influencing government policy (44), the study uses tobacco tax payments as a measure of the tobacco industry's influence.

To measure the pressure of the central policy, the study examines the tobacco control policies on public places issued at the national level from 2011 to 2021, obtaining a total of 37 policy texts (see Supplementary Table S1). These texts include different policy categories, such as departmental normative documents, departmental regulations, State Council normative documents, administrative regulations, and legal working documents, all of which have made relevant provisions on "smoking behavior in public places." The policy pressure is the number of policy documents on tobacco control in public places issued in the previous year. Given that the effects of policies may have a certain time lag, the study further uses $t-2$ data for the robustness test of the central policy pressure.

4 Results

4.1 Comprehensive smoke-free policies in provincial capitals and above in China

By using the keywords "city name," "public places," and "smoking," this study conducted a search and review of the smoke-free policies texts issued by various cities through the Chinese Laws and Regulations Database and the official websites of each city government.

TABLE 1 Variables and measurement.

Variable name	Measurement description
Dependent variable (Y)	
Policy adoption	A binary variable assigned 1 if city *i* adopts a comprehensive smoke-free policy in year *t* and city *j* had already adopted the policy in year $t-1$ or earlier; otherwise, it is 0.
Independent variables (X)	
Scientific evidence	Assigned 1 if city *i* conducted surveys on tobacco prevalence or secondhand smoke exposure in year $t-1$; otherwise, it is 0.
Focal events	Assigned 1 for the year and the two years prior to when city *i* hosts significant international events; otherwise, it is 0.
Media coverage	The number of news reports related to smoking control in city *i* in the given year (in thousands).
Policy foundations	The number of smoking control policies in public places enacted in city *i* by the end of the previous year.
Horizontal policy diffusion-economic comparison	Assigned 1 if city *j*'s *per capita* GDP in year $t-1$ is higher than that of city *i*; otherwise, it is 0.
Horizontal policy diffusion-administrative level difference	Municipalities directly under the central government are scored as 3, subprovincial cities as 2, and other non-subprovincial capital cities as 1. The score for this item is the difference between the administrative level score of cities *j* and *i*.
Central policy signals	The number of policies issuing public smoking control by the central government in year $t-1$.
Influence of health departments	The proportion of healthcare expenditure to the general budget expenditure of city i in year $t-1$ (in %).
Influence of tobacco control groups	Encoded as 1 if city *i* was selected for the smoke-free city legislation project in year $t-1$; otherwise, it is 0.
Influence of the tobacco industry	The percentage of total tobacco tax revenue to the total tax revenue of city *i*/province in year $t-1$ (in %).

As of December 31, 2021, a total of 107 regulations or rules related to smoke-free policies were obtained from 36 cities (including amendments). The policy texts were evaluated on an article-by-article basis with reference to Article 8 of the WHO FCTC and its implementation guidelines for a smoke-free environment, and cities that achieve a smoke-free environment should meet the following criteria: "Smoke-free places should cover all indoor public spaces. Smoke-free places should cover all indoor public places, indoor workplaces, and public transportation," or at least the eight categories recommended by the WHO (i.e., healthcare facilities, schools, universities, government facilities, offices, restaurants, bars and other entertainment venues, and public transport) if they are enumerated as smoke-free places (45). The policy texts must not allow designated smoking areas, and if a transition period is set, then a specific end date must be clearly stated (46). The specific assessment results for each city are provided in Supplementary Table S2. Ultimately, out of China's 36 provincial capitals and cities above, 13 cities have enacted comprehensive smoke-free policies in public places, namely, Qingdao, Shenzhen, Lanzhou, Beijing, Nanning, Shanghai, Changchun, Xi'an, Hangzhou, Wuhan, Harbin, Zhengzhou, and Xining.

4.2 Descriptive statistics

Table 2 presents the descriptive statistics for the main variables of this study.

The mean value of the dependent variable, policy adoption, is 0.045, indicating a 4.5% probability of policy adoption occurrence within the observed 1,575 samples. In terms of the problem stream-related variables, 33.5% of the samples conducted scientific surveys related to tobacco prevalence, highlighting the attention cities pay to scientific evidence in the policy process. The probability of focal events, namely, major international activities, is 22.7%, mainly involving cities of Beijing, Shanghai, Nanning, Hangzhou, Shenzhen, Nanjing, Qingdao, Tianjin, and Wuhan. A significant variation exists in tobacco control media coverage among the observed cities, with a maximum value of 17.353 (thousand articles) and a minimum value of just 0.014 (thousand articles). In terms of variables related to the policy stream, the institutional foundation varies among cities. Fuzhou, Changsha, and Taiyuan were later in issuing policy texts related to smoking control in public places, with these cities issuing relevant policy texts in 2015, 2018, and 2016, respectively. In terms of the variables related to political stream, the central policy signal values range from a maximum of 6 to a minimum of 1, indicating significant differences in the number of tobacco control policies issued at the central level. The maximum value for the tobacco industry influence indicator is 43.447, representing the percentage of tobacco taxes in Kunming's total tax revenue in 2016, whereas the minimum value is for Dalian in 2014, where tobacco industry taxes accounted for only 0.454% of the city's total tax revenue.

Table 2 also reports the variance inflation factor (VIF) for each variable, all below 10, with the highest at 1.66, suggesting a low likelihood of multicollinearity among the variables and that a strong degree of independence exists among the variables.

4.3 Logit regression model results

The study incrementally incorporated three sets of independent variables into the models for analysis. Models 1–3 are single-dimensional models, Models 4–6 are two-dimensional combination models, and Model 7 is a full model that incorporates all explanatory variables into the regression analysis. The results of the logit regression models are presented in Table 3.

The pseudo R^2 represents the model fit. All models are significant at the 0.01 level. Model 7 has the highest pseudo R^2 at 0.748, indicating that it can explain 74.8% of the variance in the dependent variable. Among the single variable models, Model 1 has the highest pseudo R^2, suggesting the problem stream has the strongest explanatory power for the dependent variable, followed by the political and policy

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TABLE 2 Descriptive statistical results of main variables.

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum	VIF
Policy adoption	1,575	0.045	0.208	0	1	/
Scientific evidence	1,575	0.335	0.472	0	1	1.14
Focal events	1,575	0.227	0.419	0	1	1.23
Media coverage	1,575	1.407	1.576	0.014	17.353	1.65
Policy foundations	1,575	6.524	3.703	0	17	1.35
Horizontal policy diffusion-economic comparison	1,575	0.62	0.486	0	1	1.37
Horizontal policy diffusion-administrative level difference	1,575	0.402	0.943	−2	2	1.66
Central policy signals	1,575	3.326	1.973	1	6	1.11
Influence of health departments	1,575	7.217	1.616	2.77	11.750	1.05
Influence of tobacco control groups	1,575	0.208	0.406	0	1	1.40
Influence of the tobacco industry	1,575	6.939	7.139	0.454	43.447	1.14

streams. The full model has the highest fit among all models, indicating that policy adoption results from the interaction of multiple variables.

For variables related to the problem stream, scientific evidence, focal events, and media coverage significantly influence the adoption of comprehensive smoke-free policies in Models 1, 4, 5, and 7, all with positive effects, and H1, H2, and H3 pass the significance test at the 0.01 level. Specifically, with other variables controlled, the more comprehensive the scientific evidence is, the city being in a major international event cycle, and the more tobacco control media coverage is, the more likely the city will introduce a comprehensive smoke-free policy.

For the policy stream-related variables, institutional foundation passes the significance test at the 0.01 level in Models 2, 4, 6, and 7, whereas economic comparison and administrative level differences only pass in Model 7. Institutional foundation and economic comparison have positive effects, which indicates that the more smoking-related policies a city has issued and the higher the economic level of other cities that have adopted comprehensive smoke-free policies, the more inclined the city will be to introduce such policies. Administrative-level differences have negative effects, indicating that the smaller the difference in administrative levels between cities is, the more likely imitation behavior will occur. That is, if other cities of similar administrative level introduce comprehensive smoke-free policies, then the city is more likely to adopt such policies. H4, H5, and H6 pass the significance test at the 0.01, 0.1, and 0.05 levels, respectively, in Model 7.

Regarding variables related to the political stream, central policy signals pass the significance test at the 0.01 level in Models 3, 5, 6, and 7, with a negative correlation. This result indicates that the stronger the policy signals in the tobacco control field released by the central government are, the less likely the local governments will adopt comprehensive smoke-free policies. Actor influence shows that the health departments and tobacco control groups have significantly positive effects on policy adoption, whereas the tobacco industry's influence has a significantly negative effect. This result indicates that actions by the health system and tobacco control groups promote local policy adoption of comprehensive smoke-free policies, whereas the tobacco system hinders it. In Model 7, H8, H9, and H10 pass the significance test at the 0.01, 0.01, and 0.05 levels, respectively.

Model 7 further analyzes the effects of various variables on policy adoption. Scientific evidence, the influence of tobacco control groups, and focal events are key to policy adoption, with coefficients in Model 7 of 4.174, 3.743, and 3.720 and odds ratios of 64.97, 42.22, and 41.26, respectively. Media coverage, institutional foundation, economic comparison, and the influence of health departments have odds ratios of 3.52, 1.86, 3.90, and 3.91, respectively. This result indicates that for every additional thousand articles of tobacco control media coverage, the odds of a city introducing a comprehensive smoke-free policy increase by 3.52 times; for every additional policy related to smoking control, the odds increase by 86%; if higher GDP level cities have adopted comprehensive smoke-free policies, the odds increase by 2.9 times; and for every percentage increase in public health spending, the odds increase by 2.91 times. Administrative level differences, central policy signals, and tobacco industry influence negatively affect policy adoption, with odds ratios of 0.38, 0.55, and 0.63, respectively. This outcome implies that for every unit increase in city level difference, the odds decrease by 62%; for every unit increase in central policy signal strength, the odds decrease by 45%; and for every percentage increase in tobacco industry tax contribution, the odds decrease by 37%.

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TABLE 3 Results of the logit regression model.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	Regression coefficient	Regression coefficient	Regression coefficient	Regression coefficient	Regression coefficient	Regression coefficient	Regression coefficient
Scientific evidence	2.998*** (0.464)			3.499*** (0.564)	3.865*** (0.816)		4.174*** (0.945)
Focal events	2.451*** (0.424)			2.782*** (0.480)	3.768*** (0.844)		3.720*** (1.295)
Media coverage	1.024*** (0.148)			0.960*** (0.147)	1.153*** (0.233)		1.260*** (0.330)
Policy foundations		0.155*** (0.041)		0.241*** (0.075)		0.139*** (0.053)	0.621*** (0.196)
Economic comparison		0.076 (0.327)		0.527 (0.505)		0.233 (0.404)	1.363* (0.755)
Administrative level difference		−0.215 (0.189)		−0.143 (0.300)		−0.240 (0.241)	−0.940** (0.409)
Central policy signals			−0.326*** (0.089)		−0.401*** (0.142)	−0.341*** (0.092)	−0.593*** (0.183)
Influence of health departments			−0.356*** (0.115)		0.875*** (0.325)	−0.393*** (0.120)	1.364*** (0.479)
Influence of tobacco control groups			4.012*** (0.395)		4.709*** (0.970)	3.930*** (0.391)	3.743*** (0.762)
Influence of the tobacco industry			−0.081*** (0.031)		−0.507*** (0.160)	−0.042 (0.032)	−0.463** (0.192)
Observation	1,575	1,575	1,575	1,575	1,575	1,575	1,575
Pseudo *R*-squared	0.576	0.121	0.370	0.600	0.709	0.384	0.748
Log lik.	−122.804	−254.320	−182.478	−115.893	−84.158	−178.318	−72.936
Chi-squared	333.246***	70.215***	213.342***	347.070***	410.539***	222.220***	432.984***

Standard errors are in parentheses; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

4.4 Robustness test

Given that the dependent variable data in this study are unbalanced, with the occurrence probability of policy adoption being only 4.5%, there might be a rare events bias. Therefore, the study considers using a relogit model, which is suitable for rare events data, to conduct a robustness test (47). The relogit model regression results (see Table 4) indicate that all 10 independent variables have significant effects on the dependent variable, and the conclusions are consistent with those from the logit model regression results. This finding demonstrates that the study's conclusions exhibit strong robustness.

Given multi-level governance pattern, there may be delays in the transmission of central policy to local governments. In case there may be a lag effect of central policy, we conduct a lag analysis in the statistical model, using $t-2$ data for the central policy signals variable in the logit analysis. The results (see Table 5) show that the $t-2$ central policy signal variable is not significant. When $t-1$ and $t-2$ data are included in the model simultaneously, the results shows a negative correlation for $t-1$, while $t-2$ remains insignificant. These results are consistent with the baseline logit model.

5 Discussion

On the basis of the specific context of tobacco control policy formulation in China, this study proposes an analytical framework of the factors influencing the adoption of comprehensive smoke-free policies by local governments by applying the multiple streams framework, which is a classic theory in policy process research. It then empirically tests this framework using the EHA method. Statistical results show that all 10 core independent variables significantly influence the adoption of comprehensive smoke-free policies in cities, supporting the related hypotheses. Specifically, scientific evidence, focal events, media coverage, institutional foundation, economic comparisons, and the influence of health departments and tobacco control groups all positively affect policy adoption, whereas differences in administrative levels, central policy signals, and the influence of the tobacco industry have negative effects.

Scientific evidence, focal events, and media coverage constitute the problem stream for smoke-free policies, shaping policymakers' perception of the severity of public place smoking issues. This study validates the successful experience of tobacco control policy making

abroad that the future of developing smoke-free policies depends on reliable scientific data (48). Scientific data provide strong scientific support for decision makers to focus on public place smoking issues. Before initiating smoke-free policy formulation, conducting scientific tobacco prevalence surveys and collecting local tobacco harm evidence in the city become prerequisites for successful policy advocacy. Moreover, linking scientific evidence with political backgrounds and utilizing the "spillover effect" of other issues can effectively increase attention to the issue. For example, when preparing evidence for smoke-free environment policy, the health department of Chongqing paid particular attention to the negative effect of smoking on the poor, responding to China's political goal of poverty alleviation. Focal events, mainly planned and foreseeable events, create an opportunity for cities to introduce smoke-free policies and opens a "policy window," a feature that is particularly evident in the early stages of smoke-free advocacy (49). Cities such as Beijing, Shanghai, Hangzhou, Wuhan, and Nanning all took advantage of this critical timing to promote local smoke-free legislation. Given that major international events are predictable, tobacco control advocates should emphasize and take advantage of this opportunity to push comprehensive tobacco control policies onto government agendas. Media coverage shows a strong positive correlation with local governments adopting comprehensive smoke-free policies. Successful tobacco control advocacy is a process of broad expression and gaining acceptance by multiple stakeholders, especially tobacco control alliances, where mainstream media significantly becomes a conduit and platform for advocacy "upwards" and "downwards" (50). Following communication laws, accumulating, excavating, and releasing the public opinion momentum of macro social contexts and public issues remain an important strategy that should be adhered to and improved in future tobacco control communication.

Institutional foundation and horizontal policy diffusion significantly influence decision makers' consensus on policy proposals. The existing institutional foundation significantly affects local governments' adoption of comprehensive smoke-free policies. In China's tobacco control practices, many cities have gradually aligned their public place smoking control laws and regulations with the convention requirements through multiple revisions, ultimately facilitating the introduction of comprehensive smoke-free policies. In view of the continuity and gradual nature of China's public policy formulation (51), policy introductions often undergo minor modifications based on existing foundations, presenting a "spiral upward" trend. Policy practices from other regions also influence policy adoption behaviors, with local governments tending to imitate cities of similar administrative levels and stronger economic strength. Therefore, actively creating and disseminating exemplary cases of comprehensive smoke-free cities, as well as fully leveraging the demonstrative effect of star cities in tobacco control through research and learning activities, is an important practical path to encourage other cities to adopt comprehensive smoke-free policies.

TABLE 4 Results of relogit model regression.

Variable	Relogit
Scientific evidence	3.359*** (3.798)
Focal events	2.007*** (1.532)
Media coverage	1.295** (0.517)
Policy foundations	0.698*** (0.192)
Horizontal policy diffusion-economic comparison	1.338** (0.399)
Horizontal policy diffusion-administrative level difference	−0.839** (0.350)
Central policy signals	−0.466*** (0.142)
Influence of health departments	1.381*** (0.489)
Influence of tobacco control groups	3.664*** (0.275)
Influence of the tobacco industry	−0.461* (0.252)

***, **, and * denote significance levels at 1, 5, and 10%, respectively. Standard errors are in parentheses.

The negative effects of central policy signals derived from this study differ from conclusions in previous policy formulation or policy innovation diffusion research. Why does a stronger central policy signal decrease the likelihood of local governments adopting comprehensive smoke-free policies? Although the central level in China continuously releases signals for smoke-free environment construction, the policy influence of related documents is limited. Most tobacco control policy documents are issued by health system departments, such as the National Health Commission and the Patriotic Health Campaign Committee, not yet breaking out of the health system to influence cross-sectoral and cross-departmental areas. Moreover, tobacco control policies often appear in forms such as "opinions," "notices," and "plans," dominated by advisory clauses such as "encourage," "advocate," and "support," lacking authoritative enforcement. The study shows that persistently pushing for national-level public place smoke-free legislation remains a core task for future policy advocacy. The interplay among actors involved in smoke-free environment policies, especially the tobacco industry, is complex and merits attention. This study indicates that the greater the economic dependence on tobacco is, the less likely the introduction of comprehensive smoke-free policies will be. China's tobacco tax data show that national tobacco taxes and profits continue to increase annually, even in cities including Harbin, Changchun, and Xining, which have introduced comprehensive tobacco control policies, with tobacco contributions increasing rather than decreasing. The COVID-19 pandemic has further intensified local governments' dependence on the tobacco economy. In the process of formulating tobacco control policies, vigilance is crucial regarding the tobacco industry's use of economic interests as a leverage in negotiations to influence decision makers and ultimately impede the introduction of a comprehensive smoke-free policy.

6 Conclusion

This study constructs an analytical framework of factors influencing the adoption of comprehensive smoke-free policies by local governments in China. The framework is based on the three source-flow elements of the multiple streams framework and is tailored through discussions with existing research and the Chinese tobacco control policy scenario. The analytical framework is an adaptation and refinement of the multiple streams framework to the Chinese policy scenario. The study also collects panel data from 36 provincial capitals and other major cities across China from 2013 to 2021. Then, it statistically tests the variables in the analytical framework using logit models with directed dyad-year EHA

TABLE 5 Results of central policy signals' lag analysis.

Variable	Model 8	Model 9
Scientific evidence	3.688*** (0.725)	3.989*** (0.923)
Focal events	2.436*** (0.584)	2.603** (1.288)
Media coverage	0.931*** (0.184)	0.728*** (0.352)
Policy foundations	0.531*** (0.172)	0.607*** (0.195)
Horizontal policy diffusion-economic comparison	0.977 (0.710)	1.341* (0.762)
Horizontal policy diffusion-administrative level difference	−0.425 (0.368)	−0.897** (0.418)
Central policy signals ($t-1$)		−0.588*** (0.183)
Central policy signals ($t-2$)	0.132 (0.156)	0.099 (0.185)
Influence of health departments	0.890** (0.348)	1.264** (0.497)
Influence of tobacco control groups	2.727*** (0.518)	3.741*** (0.777)
Influence of the tobacco industry	−0.302** (0.136)	−0.474** (0.199)

***, **, and * denote significance levels at 1, 5, and 10%, respectively. Standard errors are in parentheses.

methodology. The statistical results show that scientific evidence, focal events, media coverage, institutional foundations, horizontal policy diffusion (including learning and imitation mechanisms), central policy signals, and actor influence (including the influence of the health sector, tobacco control groups, and the tobacco system) have significant effects on the adoption of a comprehensive smoke-free policy in a city. Particularly, imitation mechanism, key policy signal, and tobacco industry influence have negative effects, whereas all other variables have positive effects.

6.1 Theoretical contributions

On the basis of the multiple streams framework, this study constructs and validates an analytical framework for analyzing the factors influencing the adoption of comprehensive smoke-free policies in key Chinese cities based on the Chinese context. Through EHA, the study validates the core idea of the multisource flow framework (i.e., that policy outcomes are the result of the combined effect of issues, policies, and political flows). When all variables are included in the regression analysis (i.e., the full model), the model has the highest pseudo R^2, suggesting that policy adoption behavior will likely to occur under the combined effects of issues, policies, and political flows. Conversely, differences exist in the positive or negative effects of different factors on policy adoption. Some interesting phenomena are observed. For instance, the national output of tobacco control policy signals did not promote the adoption of a comprehensive smoke-free policy at the local level, and the two were negatively correlated. The study enhances the understanding of policy practices with Chinese characteristics and enriches the applicability and explanatory power of the multiple streams framework to local-level policy processes.

6.2 Policy implications

In recent years, health policy has gradually become the focus of domestic public management scholars, but the policy areas of concern are still dominated by "high-attention" areas or emergencies, such as healthcare reform, hospital management, and infectious disease outbreaks, whereas insufficient attention has been paid to "low-attention" policy areas. In the context of China's epidemiological transition, chronic non-communicable diseases have replaced infectious diseases as the primary risk factor threatening people's health, and the previous situation of "focusing on treatment but not on prevention" urgently needs to be changed. Thus, research on a large number of non-emergency and low-attention policy areas is conducive to the development of the Healthy China policy and will provide some inspiration for the modernization of the national governance system and governance capacity.

The three source stream framework developed in this study provides a practical guide for advancing tobacco control advocacy. Specifically, in the issue stream, tobacco control advocates can raise policymakers' awareness of the seriousness of the problem of tobacco control in public places by fully exploring scientific evidence, seizing key policy windows, and strengthening communication and cooperation with the media. In the policy stream, the central government should be encouraged to send clear and binding policy signals. This will encourage local governments to follow and implement policies rather than just "pass through" them; bring into play the roles and functions of different policy subjects in the policy-making process; fully mobilize the health sector and tobacco control groups to participate in the policy-making process; and be wary of the tobacco industry's negative influence on tobacco control.

6.3 Limitations and recommendations

The study has the following limitations that need to be improved in subsequent studies. First, although the quantitative analysis hints at a causal relationship between the influencing factors and policy adoption, it still does not fully open the black box of policy-making. Future studies would benefit from employing other research methods, such case study and process tracking method, should be used in further analyzing the coupling mechanism among those streams. Second, due to data availability, the research focused on the most representative of China's 36 provincial capitals and above. However, recent years have seen cities such as Zhangjiakou, Qinhuangdao, and Dandong, which are not provincial capitals, also enact comprehensive smoke-free policies. These cities, may have fewer resources for policy advocacy compared with provincial capitals, but they offer valuable lessons on overcoming policy barriers. Their experience warrant attention in future research. Third, the study is conducted in the context of China's political system, and the explanatory power of the findings for countries with other political systems needs to be further verified in future research.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

WF: Conceptualization, Methodology, Writing – original draft. BQ: Data curation, Writing – review & editing. XJ: Data curation, Writing – review & editing. SL: Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Secondhand tobacco smoke exposure in homes and vehicles in youth: disparities among racial, and sexual and gender minorities

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Background: Secondhand smoke exposure (SHSe) among youth is a serious public health concern, leading to an increased risk of conditions such as asthma and respiratory infections. However, there is little research on SHSe among vulnerable populations, such as racial and sexual minorities. Understanding the factors associated with youth SHSe in homes and vehicles is crucial to developing better protective policies.

Methods: This study utilized 2020 data from the National Youth Tobacco Survey, a representative sample of middle- and high-school students in the US. The primary outcomes were youth SHSe at home and while riding in a vehicle. Multinomial regression models were used to assess factors associated with SHSe.

Results: The data included 9,912 students enrolled in grades 6 through 12 in the United States who reported never using any form of tobacco. Non-Hispanic Black students living with someone who does not use any form of tobacco products were significantly more likely to experience moderate [OR = 2.1 (1.1–3.9), $p = 0.03$] and severe [OR = 5.1 (2.2–11.7), $p < 0.001$] secondhand smoke exposure (SHSe) in homes compared to their non-Hispanic White counterparts. Heterosexual female students had lower odds of reporting moderate SHSe in the home compared to heterosexual males [OR = 0.7 (0.6–0.99), $p = 0.02$], whereas bisexual females had two-fold increased odds of severe SHSe in homes [OR = 2.0 (1.2–3.4), $p = 0.01$].

Conclusion: Significant efforts are needed to develop targeted interventions to reduce SHSe in homes and vehicles, particularly in these vulnerable populations.

KEYWORDS

secondhand tobacco smoke exposure, racial disparities, sexual minorities, adolescents, National Youth Tobacco Survey

Introduction

Secondhand smoke exposure (SHSe) causes serious health issues in non-smoking adults and children as they are inhaling many of the same harmful toxins as active smokers do (1–5). Longer durations and higher levels of SHSe can increase the risk of lung cancer (3, 4). SHSe has been reported to lead to several conditions in children, such as more frequent and severe asthma attacks, respiratory infections, impaired lung functions, and ear infections (3, 4, 6). SHSe has also been associated with a higher risk of ischemic heart disease, stroke, and type 2 diabetes (4). A systematic literature review found that prenatal or postnatal SHSe was associated with a risk of lower birth weight, stunted height, wasting, and a lower head circumference (7). Children who lived with a smoker for over a decade were associated with having higher mortality from chronic obstructive pulmonary disease (8).

There are several laws at local and state levels to ensure that all non-hospitality workplaces, restaurants, and bars are 100% smoke-free that have been successful in reducing SHSe (9). Public smoking bans have been beneficial in decreasing incidents of acute coronary events such as heart attacks and acute myocardial infarctions (10). Furthermore, The U.S. Surgeon General recommends that parents protect their families by not allowing smoking anywhere in their homes or cars, ensuring their children's schools are tobacco-free, and avoiding locations that allow smoking (2). SHSe in areas such as homes and vehicles is especially dangerous, as tobacco smoke in enclosed spaces can produce extremely unhealthy levels of Particulate Matter 2.5, an air pollutant that can negatively impact respiratory and cardiovascular function (11).

Adolescent never-smokers exposed to secondhand smoke at home are also at an increased risk for initiating smoking compared to those not exposed (12). Many states have implemented smoke-free policies, particularly in subsidized and public housing, to minimize health risks. However, enforcement remains inconsistent, and some states rely on voluntary compliance by landlords, limiting the impact of these policies. As of December 31, 2023, only 16 states have enacted smoking restrictions for public or private multi-unit housing. Among these, 14 of the states restrict smoking in common areas only, despite the risk of secondhand smoke infiltrating residential units from other spaces (13).

Evidence also suggests that SHSe in a motor vehicle may lead to nicotine-dependent symptoms (e.g., physical and mental cravings, susceptibility to environmental cues) in 10–12 year-olds (14).

Importantly, there is broad support for prohibitions on smoking in vehicles when children under the age of 13 are present (15). However, only thirteen states specifically prohibit smoking in vehicles used to transport children in childcare facilities. Only, 11 states prohibit smoking in personal vehicles when children are present (16).

The US surgeon general's recommendation and existing state laws aimed at reducing SHSe have been effective in reducing SHSe prevalence in the US (87.5% in 1988 to 25.3% in 2012) (17), however, they have stagnated in following years (25.3% in 2012 to 24.6% in 2018), and inequalities still exist in particular demographics (4, 17–19). According to 2011–2018 National Health and Nutrition Examination (NHANES) data (18), SHSe was higher among youth aged 3–11 and 12–19 compared to adults over 20 years old. Non-Hispanic Black individuals also had a higher prevalence of exposure compared to non-Hispanic White individuals and Mexican Americans. Furthermore, those living below the poverty level had over two-fold increased prevalence compared to those who live at or above it. SHSe prevalence for renters was also double compared to those who owned their homes. Lastly, those who lived with a smoker in the home also had a higher prevalence compared to those who lived in a home with no smokers (18).

The prevalence of tobacco use varies by sexual orientation identity (20, 21). The use is substantially higher among sexual and gender minorities compared to heterosexual individuals (22). Furthermore, individuals who identify themselves as bisexual have a higher cumulative incidence of starting smoking at an earlier age compared to heterosexuals (20). The high tobacco use is attributed to be a coping mechanism brought upon by the stress and stigma (23). Although there have been several studies assessing tobacco use and trends among sexual minorities, little is known about SHSe in this vulnerable group.

SHSe also creates a burden on the healthcare system and economy. Research shows that healthcare costs from SHSe are declining. However, the costs are still substantial and avoidable ($4.6 billion in 2000, $2.1 billion in 2005, and $1.9 billion in 2010) (24). Overall, SHSe resulted in an estimated 42,000 deaths and $6.6 billion of lost productivity in 2006 (25) and $6.5 billion loss in 2009, which is equivalent to $8.2 billion in 2017 dollars (26). School children with an adult(s) who smoked in the home were more likely to have school absences than those who did not live with smokers, which is valued at an estimated $227 million loss in their caregivers' work productivity (27).

There is strong public support for implementing smoke-free policies to keep children safe, with the highest levels of support found for places frequented by children, such as cars carrying children (86%) and playgrounds (80%) (28), particularly, with non-smokers, former smokers, and women showing higher levels of support. Despite official recommendations, successful public policies, and individual support, SHSe in private spaces remains a concern. A report utilizing the 2016 National Youth Tobacco Survey found that 29% of U.S. youth were exposed to SHSe at least one day during the past 7 days at home or in a vehicle SHSe (29). Another study (30) utilizing the 2019 National Youth Tobacco Survey data reported that SHSe prevalence at homes was 25.3% and in vehicles was 23.3% among US middle and high school students. The report also found that SHSe in homes declined significantly from 2011–2018, except for non-Hispanic Black students. Even though these studies evaluated the prevalence of SHSe, the degree and severity of SHSe and the associated factors in different subpopulations have not been studied in the literature. We hypothesize that the degree of SHSe will significantly vary among racial, sexual, and gender minorities.

Overall, children experience SHSe more frequently than adults, and it most frequently occurs within the home (31). Even when young individuals abstain from tobacco products, they can still be exposed to SHSe in situations beyond their control, such as in family homes and vehicles. Therefore, this study aims to identify racial, sexual, and gender disparities in exposure to secondhand smoke among youth in homes and while they ride a vehicle. Addressing these disparities is vital for developing effective public health interventions and protecting vulnerable populations.

Methods

Data and sampling design

This study utilized data from the 2020 cycle of the National Youth Tobacco Survey (NYTS). NYTS is a cross-sectional survey developed

to collect data to evaluate tobacco prevention and control programs and is representative of middle and high school students in the United States (32). The survey design of NYTS consists of a three-stage cluster sample design. The first stage samples primary sampling units, which are counties or a group of small counties; the second stage comprises selecting secondary sampling units, which are schools within each of the selected primary sampling units; and the third stage comprises selecting classes within each grade level of the selected school. The survey was administered to all students within a selected class. Participation in the NYTS is voluntary at both the student and school levels. The survey design was stratified by several factors at each sampling stage. The primary sampling units were stratified by race/ethnicity and urban vs. non-urban designation. Then, the schools were stratified by their size (small, medium, and large) and educational level (middle school vs. high school). The survey data was collected electronically, maintaining confidentiality. The 2020 NYTS survey data was rigorously checked to confirm its representativeness and minimize bias despite data collection being interrupted due to COVID-19. The sample was verified against various demographic, geographic, and socioeconomic characteristics to ensure precise estimates for key subgroups. Specifically, the sample was confirmed as representative by comparing the distribution of participating schools with the broader subset of agreeing schools across U.S. regions (South, East, Midwest, and West), school types (public and non-public), and educational levels (middle and high schools).

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline. The Office of Management and Budget (OMB), ICF's Institutional Review Board (IRB), and CDC's Institutional Review Board (IRB) approved the NYTS cycles used in this study. Because the NYTS data were deidentified and publicly available, our secondary data analysis was exempt from institutional review board approval.

Outcome

The primary outcomes of this study were youth exposure to secondhand tobacco smoke at home and while riding in a vehicle. The study population included only those students who have never used any form of combustible or noncombustible tobacco products in order to avoid confounding responses from smokers and to characterize the smoke exposure as purely secondhand. The primary outcomes were obtained from two questions: "During the past 7 days, on how many days did someone smoke tobacco products in your home while you were there?" and "During the past 7 days, on how many days did you ride in a vehicle when someone was smoking a tobacco product?." The responses for both questions were categorized into three levels: (1) No Exposure: Exposed for 0 days in the past 7 days; (2) Moderate Exposure: Exposed for 1–4 days in the past 7 days; (3) Severe Exposure: Exposed for 5–7 days in the past 7 days.

Statistical analysis

Because the NYTS is based on a three-stage cluster sampling design, survey-adjusted weights were used to estimate the prevalence of SHSe. The base sampling weight for each student was calculated using the inverse probability of selection at each stage. These base weights were adjusted for nonresponse by sex and grade level within each school. These weights were then further adjusted using a poststratification approach to match national estimates of student counts in middle and high schools by age, sex, and race/ethnicity categories.

As the two outcomes of interest had three levels, we employed a survey-weighted multinomial regression approach to identify factors associated with SHSe in homes and while riding a vehicle. Multinomial regression was chosen as the appropriate statistical method because the outcome variables are categorical with more than two levels, and the model allows for the simultaneous comparison of multiple outcome categories without assuming the proportionality of the odds ratios. All variables included in the models were selected *a priori* based on their significance and relevance to the research question. It is important to note that we did not conduct stepwise or any other model selection processes, as these approaches can inflate the type 1 error rate (33). The 'svymultinom' method from the R package 'svrepmisc' was used to model the multinomial regression. These analyses were adjusted for age, sexual/gender identity, educational level, race/ethnicity, and whether or not the students were living with someone who used tobacco products. All analyses were performed using the 'survey' package in R version 4.0.3. The significance level was calculated using a two-sided Wald test for all statistical analyses and defined as $p \leq 0.05$.

Results

Characteristics of the study population

The data from the 2020 NYTS included 14,531 students (Weighted $N = 27{,}563{,}807$) enrolled in grades 6 to 12 in the United States. Among these, 9,912 students (Weighted $N = 18{,}447{,}190$) reported they never used any form of tobacco and, thus, were the study population of interest. Table 1 shows the composition of the study population by select characteristics. 47.5% were non-Hispanic White individuals, 12.5% were non-Hispanic Black individuals, and 25.8% were Hispanics. 49.8% were female, 4.3% self-identified as bisexual females, and 39.7% self-identified as heterosexual females. Among those who did not live with a tobacco user in their homes, 32.8% were non-Hispanic White individuals, 8.2% were non-Hispanic Black individuals, and 19.9% were Hispanics. Whereas among those who lived with a combustible tobacco user in their homes, 12.8% were non-Hispanic White individuals, 3.2% were non-Hispanic Black individuals, and 5.4% were Hispanics.

Prevalence of SHSe in homes

Overall, among students who do not use any form of tobacco, 84.9% (83.2–86.4) reported no SHSe, 7.5% (6.5–8.5) reported moderate SHSe, and 7.7% (6.8–8.6) reported severe SHSe in homes (Table 2). Non-Hispanic white students who lived with individuals who do not use any tobacco products had SHSe prevalence of 1.8% (1.3–2.5) and 0.5% (0.3–1.1) for moderate and severe SHSe in homes, respectively. On the other hand, these prevalences were 3.7% (2.2–6.2) and 2.7% (1.8–4.0) for non-Hispanic Black students and 3.1% (2.5–3.8) and 1.0% (0.6–1.7) for Hispanic students who lived with

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TABLE 1 Survey weighted prevalence of select characteristics among middle- and high-school students who have never used any form of tobacco—National Youth Tobacco Survey, 2020.

Variable	Percentage (95% CI)	*N* (Weighted *N*)
SSE at home		
No exposure	84.9 (83.2–86.4)	8,255 (15437260)
Moderate exposure	7.5 (6.5–8.5)	738 (1358980)
Severe exposure	7.7 (6.8–8.6)	766 (1394543)
SSE in car		
No exposure	87.6 (86.1–89.0)	8,477 (15854114)
Moderate exposure	8.7 (7.7–9.7)	850 (1567378)
Severe exposure	3.7 (3.1–4.4)	375 (671546)
Sex		
Female	49.8 (48.4–51.2)	5,033 (9161147)
Male	50.2 (48.8–51.6)	4,852 (9233994)
Sexual identity		
Heterosexual	82.9 (81.6–84.0)	7,936 (14876371)
Gay or lesbian	2.2 (1.9–2.6)	207 (400768)
Bisexual	5.5 (4.8–6.3)	519 (992727)
Not Sure	9.4 (8.2–10.6)	942 (1679606)
Sex-sexual identity		
Male-heterosexual	43.3 (41.8–44.8)	4,044 (7755252)
Female-bisexual	4.3 (3.7–4.9)	399 (765330)
Female-gay or lesbian	1.3 (1.0–1.6)	121 (227684)
Female-heterosexual	39.7 (38.1–41.3)	3,886 (7112231)
Female-not sure	4.7 (4.0–5.4)	484 (840151)
Male-bisexual	1.2 (0.9–1.6)	115 (216823)
Male-gay	0.9 (0.7–1.2)	83 (165310)
Male-not sure	4.7 (4.0–5.5)	456 (837259)
School type		
High school	45.3 (39.3–51.4)	4,018 (8338905)
Middle school	54.7 (48.6–60.7)	5,871 (10066635)
Race/Ethnicity		
Non-Hispanic White	47.5 (42.3–52.8)	4,260 (8522709)
Non-Hispanic Black	12.5 (10.0–15.4)	1,117 (2235054)
Hispanic	25.8 (21.8–30.1)	2,888 (4621087)
Other	14.2 (10.9–18.4)	1,340 (2554583)
Spoken language		
English	67.1 (62.6–71.3)	6,164 (12196524)
Other than English	32.9 (28.7–37.4)	3,606 (5983372)
Tobacco use of co-inhabitants		
No tobacco use	72.1 (69.8–74.4)	6,971 (12964667)
Combustible tobacco use	24.9 (22.9–27.1)	2,417 (4479665)
Race/Ethnicity and Tobacco use of co-habitants		
NHW & not living with tobacco user	32.8 (28.6–37.3)	2,828 (5754419)
NHB & not living with tobacco user	8.9 (7.1–11.2)	793 (1566524)
Hispanic & not living with tobacco user	19.9 (16.8–23.5)	2,152 (3496730)
Other & not living with tobacco user	10.4 (7.3–14.5)	1,014 (1820882)
NHW & living with combustible tobacco user	12.8 (11.2–14.5)	1,166 (2236630)
NHB & living with combustible tobacco user	3.2 (2.5–4.1)	277 (564472)
Hispanic & living with combustible tobacco user	5.4 (4.4–6.5)	624 (939106)
Other & living with combustible tobacco user	3.7 (3.0–4.5)	287 (647244)

NHW, Non-Hispanic White. NHB, Non-Hispanic Black.

individuals who do not use any tobacco products, respectively. Among students who lived with combustible tobacco users, the moderate and severe SHSe prevalences in homes were 20.7% (17.5–24.2) and 29.0% (25.8–32.4) for non-Hispanic White individuals, 27.0% (19.0–36.8), and 31.4% (24.6–39.2) for non-Hispanic Black individuals, and 28.4% (22.8–34.8) and 21.8% (17.6–26.7) for Hispanics, respectively. For female students who self-identified as bisexuals, 11.6% (7.7–17.2) reported moderate, and 15.5% (11.2–21.0) reported severe SHSe. These SHSe prevalences are higher than those reported by heterosexual females, 6.2 (5.1–7.5) and 7.4% (6.4–8.5), respectively.

Prevalence of SHSe while riding in a vehicle

The prevalence of SHSe while riding in a vehicle was 8.7% (7.7–9.7) and 3.7% (3.1–4.4) for moderate and severe SHSe, respectively (Table 2). Among students who lived with combustible tobacco users, the moderate and severe SHSe prevalences while riding in vehicles were 23.1% (20.4–26.1) and 13.4% (10.8–16.5) for non-Hispanic White individuals, 29.7% (23.1–37.2) and 15.1% (11.0–20.3) for non-Hispanic Black individuals, and 19.0% (13.7–25.6) and 10.8% (7.7–15.1) for Hispanics, respectively. Male students who identified themselves as gay reported 16.3% (6.2–36.3) moderate and 10.0% (3.9–23.2) severe SHSe, respectively, which was higher than moderate and severe SHSe reported by heterosexual males.

Multinomial regression results for SHSe in homes

Results from the survey-weighted multinomial regression are reported in Table 3. Non-Hispanic Black students living with someone who does not use any form of tobacco products were significantly more likely to have moderate [OR = 2.1 (1.1–3.9), $p = 0.03$] and severe [OR = 5.1 (2.2–11.7), $p < 0.001$] SHSe in homes compared to non-Hispanic White individuals living with someone who does not use any form of tobacco products. Non-Hispanic White students

living with individuals who use combustible tobacco products had 21.6-fold increased odds of moderate SHSe and 98.6-fold increased odds of severe SHSe in the home compared to non-Hispanic White students who lived with someone who did not use any tobacco products. Heterosexual female students had lower odds of reporting moderate SHSe in the home compared to heterosexual males [OR = 0.7 (0.6–0.99), $p = 0.02$], whereas bisexual females have two-fold odds of severe SHSe in homes compared to heterosexual males [OR = 2.0 (1.2–3.4), $p = 0.01$].

Multinomial regression results for SHSe while riding in a vehicle

Non-Hispanic Black students living with someone who does not use any form of tobacco products were significantly more likely to report severe SHSe while riding in a vehicle compared to non-Hispanic White students living with someone who does not use any form of tobacco products [OR = 3.5 (1.5–8.0), $p = 0.005$] (Table 3). Non-Hispanic White students living with individuals who use combustible tobacco products had 9.6-fold increased odds of reporting moderate SHSe while riding in a vehicle and 33.2-fold increased odds of reporting severe SHSe compared to non-Hispanic White students who lived with someone who did not use any tobacco products.

Discussion

This study reports the prevalence of youth SHSe in homes and while riding vehicles. Importantly, we identified disparities in SHSe among youth belonging to racial, sexual, and gender minority groups. Of concern, over 15% of the youth are exposed to SHSe in homes, and over 12% are exposed to SHSe in vehicles. Of the continuing concerns, among middle- and high-school youth living at homes where at least one member uses combustible tobacco, over 22% experience moderate and over 27% experience severe SHSe in homes. Similarly, while riding in a vehicle, approximately 22% experience moderate SHSe, and over 12% experience severe SHSe. Furthermore, non-Hispanic Black individuals and Hispanics were disproportionately affected by both moderate and severe SHSe, even when living with individuals who do not use any form of tobacco products. The disproportionate risk observed among racial and ethnic minorities could be because of several factors, including but not limited to lower knowledge of the hazards of SHSe, living in multi-housing units, and the mode of transportation utilized.

Our study also identified disparities in SHSe among sexual and gender minority youth. Although heterosexual females had a lower likelihood of SHSe, bisexual females were much more likely to be exposed to severe SHSe. Previous research has shown that sexual minorities tend to use tobacco products at a higher prevalence and at an earlier age than their heterosexual peers (20, 34, 35). Some studies have reported tobacco use patterns in gender minority youth, which suggests that younger cohorts of gender minority individuals may be particularly vulnerable (36, 37). We believe our findings of higher SHSe rates (e.g., bisexual female SHSe 27.1% compared to heterosexual female 13.6%) among non-smoking gender minority youth might be due to the social clustering of gender minority youth for social and emotional support (38). Furthermore, the stress associated with social stigma, discrimination, and targeted marketing by tobacco companies (39) has led to higher smoking prevalence in this community, leading to higher SHSe among non-smoking sexual minorities than their heterosexual counterparts.

Smoke-free laws prohibit smoking in public places; however, they do not include smoking bans in private vehicles and homes. Therefore, children have little choice but to continue being exposed to secondhand smoke. Several countries, including regions in Canada and the USA, have passed legislation banning smoking in private vehicles in the presence of children (40). A recent study assessing the impact of the smoking ban in cars with children in England and Scotland found that the ban led to a 72% relative reduction and a 4.1% absolute reduction in SHSe among children 13–15 years of age (41). Another study with 11–18 year olds reported a 22% relative reduction in children's exposure to tobacco smoke in cars after accounting for the pre-existing declining trend (42). However, the stratified analyses revealed disparities in the impact of the policy, with significant reductions in exposure identified only among girls, younger children (aged 11–14), and those from less deprived backgrounds.

The observed disparities in the policy's impact highlight the need for continued monitoring and evaluation of such interventions to identify and address any unequal effects on different populations. By recognizing and responding to these disparities, policymakers can work toward ensuring that all children, regardless of their race/ethnicity or other characteristics, benefit from the protection provided by bans on smoking in private vehicles.

The disparities observed in SHSe in the US may be due to significant gaps in home and car ownership by racial and ethnic minorities. In the second quarter of 2022, significant disparities in homeownership were evident: 75% of white households owned homes compared to 45 and 48% of Black and Hispanic households, respectively. These disparities worsen exposure to secondhand smoke, particularly among Black and Hispanic households who are more likely to live in rented multi-unit housing. Shared ventilation systems and spaces make it difficult to maintain smoke-free zones, exposing children and vulnerable residents to health risks, including SHSe, and compounding existing socioeconomic inequalities (43, 44). Similarly, minorities are less likely to have access to vehicles, with 18% of Black households lacking access compared to 6% of White households. This reduced mobility worsens secondhand smoke exposure disparities, as affected groups are more likely to rely on car-pooling and shared private vehicles, leading to a higher risk of SHSe (45).

Also, tobacco smoke leaves behind a persistent chemical residue, which consists of several toxic chemicals such as nicotine and polycyclic aromatic hydrocarbons. If smoked in homes and vehicles, these chemicals accumulate in significant concentrations on surfaces. This is referred to as thirdhand smoke (THS), and it interferes with the immune system and alters the normal microbiome of the individuals who get exposed (46, 47). Secondhand smoke (SHS) and thirdhand smoke (THS) differ significantly in their chemical makeup, physical properties, and exposure routes, making policies that effectively protect against SHS potentially ineffective against THS exposure (48). Policymakers should pay specific attention to THSe when enacting laws to reduce SHSe.

Public support for smoke-free housing is increasing, even among smokers, as the benefits of cleaner indoor air become more recognized. Future improvements could include extending stricter uniform

TABLE 2 Prevalence of moderate and severe SHSe in home and while riding in a vehicle by select characteristics of youth who have never used any form of tobacco—National Youth Tobacco Survey, 2020.

Characteristics	Moderate SSE in home	Severe SSE in home	*p*-value	Moderate SSE in vehicle	Severe SSE in vehicle	*p*-value
Overall	7.5 (6.5–8.5)	7.7 (6.8–8.6)		8.7 (7.7–9.7)	3.7 (3.1–4.4)	
Sex						
Female	6.7 (5.7–8.0)	8.4 (7.4–9.4)	0.005	8.7 (7.7–9.9)	3.9 (3.1–4.9)	0.733
Male	8.3 (7.1–9.6)	6.9 (6.0–8.0)		8.6 (7.3–10.2)	3.5 (2.9–4.3)	
Sexual identity						
Heterosexual	7.2 (6.3–8.3)	7.0 (6.2–8.0)	<0.001	8.2 (7.4–9.1)	3.4 (2.8–4.1)	0.001
Gay or lesbian	10.6 (6.3–17.3)	17.2 (11.9–24.3)		12.6 (7.0–21.6)	7.3 (4.0–12.7)	
Bisexual	11.0 (7.8–15.2)	14.1 (10.7–18.2)		11.8 (8.3–16.5)	7.0 (4.8–10.1)	
Not sure	6.8 (4.1–11.2)	6.8 (5.1–9.0)		9.7 (6.7–13.9)	3.3 (2.2–4.9)	
Sex-sexual identity						
Male-heterosexual	8.2 (7.1–9.6)	6.7 (5.7–8.0)	<0.001	7.8 (6.7–9.1)	3.3 (2.6–4.2)	0.007
Female-bisexual	11.6 (7.7–17.2)	15.5 (11.2–21.0)		10.6 (7.0–15.6)	6.7 (4.0–10.9)	
Female-gay or lesbian	10.7 (6.3–17.5)	18.7 (11.8–28.3)		10.2 (5.8–17.5)	5.5 (2.6–11.2)	
Female-heterosexual	6.2 (5.1–7.5)	7.4 (6.4–8.5)		8.7 (7.6–9.8)	3.6 (2.9–4.5)	
Female-not sure	6.1 (3.5–10.5)	7.1 (4.8–10.4)		8.6 (5.6–12.9)	3.6 (2.0–6.4)	
Male-bisexual	9.3 (5.1–16.2)	9.4 (4.6–18.3)		16.8 (9.8–27.4)	8.1 (3.0–20.3)	
Male-gay	11.0 (4.0–26.7)	14.0 (6.6–27.3)		16.3 (6.2–36.3)	10.0 (3.9–23.2)	
Male-not sure	7.5 (4.3–12.9)	6.4 (4.2–9.8)		10.9 (6.7–17.3)	3.0 (1.7–5.2)	
School type						
High School	6.8 (5.8–8.0)	7.9 (6.7–9.3)	0.359	8.6 (7.4–10.0)	3.8 (3.1–4.8)	0.887
Middle School	8.0 (6.7–9.7)	7.5 (6.4–8.8)		8.7 (7.5–10.1)	3.6 (2.9–4.5)	
Race/Ethnicity						
NHW	6.9 (5.7–8.2)	8.1 (6.8–9.6)	0.007	8.9 (7.7–10.1)	3.9 (3.0–5.1)	0.001
NHB	9.8 (6.9–13.9)	10.2 (8.3–12.4)		12.1 (9.6–15.1)	5.3 (4.1–6.9)	
Hispanic	8.4 (7.1–9.7)	5.5 (4.5–6.6)		7.5 (6.1–9.3)	3.0 (2.3–4.0)	
Other	5.7 (4.0–8.2)	8.3 (5.7–11.9)		6.7 (4.8–9.2)	2.4 (1.4–4.0)	
Spoken language						
English	7.4 (6.3–8.7)	8.5 (7.5–9.7)	0.006	9.2 (8.1–10.5)	4.1 (3.4–5.0)	0.009
Other than English	7.6 (6.2–9.2)	5.8 (4.9–6.9)		7.5 (6.1–9.1)	2.9 (2.2–3.7)	
Tobacco use of co-inhabitants						

(Continued)

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TABLE 2 (Continued)

Characteristics	Moderate SSE in home	Severe SSE in home	*p*-value	Moderate SSE in vehicle	Severe SSE in vehicle	*p*-value
No tobacco use	2.4 (2.0–2.9)	1.0 (0.7–1.4)	<0.001	4.2 (3.7–4.8)	0.8 (0.6–1.1)	<0.001
Combustible tobacco use	22.7 (20.3–25.3)	27.8 (25.8–29.9)		21.9 (19.5–24.6)	12.5 (10.7–14.5)	
Race/Ethnicity and Tobacco use of co-habitants						
NHW & not living with tobacco user	1.8 (1.3–2.5)	0.5 (0.3–1.1)	<0.001	3.6 (2.9–4.5)	0.6 (0.3–1.1)	<0.001
NHB & not living with tobacco user	3.7 (2.2–6.2)	2.7 (1.8–4.0)		5.4 (3.7–7.7)	2.0 (1.1–3.6)	
Hispanic & not living with tobacco user	3.1 (2.5–3.8)	1.0 (0.6–1.7)		4.4 (3.6–5.4)	0.7 (0.4–1.2)	
Other & not living with tobacco user	1.4 (0.7–2.7)	1.1 (0.5–2.4)		3.3 (2.4–4.5)	0.3 (0.1–1.3)	
NHW & living with combustible tobacco user	20.7 (17.5–24.2)	29.0 (25.8–32.4)		23.1 (20.4–26.1)	13.4 (10.8–16.5)	
NHB & living with combustible tobacco user	27.0 (19.0–36.8)	31.4 (24.6–39.2)		29.7 (23.1–37.2)	15.1 (11.0–20.3)	
Hispanic & living with combustible tobacco user	28.4 (22.8–34.8)	21.8 (17.6–26.7)		19.0 (13.7–25.6)	10.8 (7.7–15.1)	
Other & living with combustible tobacco user	18.5 (13.7–24.5)	29.0 (21.8–37.6)		16.7 (11.7–23.2)	8.6 (5.4–13.4)	

NHW, Non-Hispanic White. NHB, Non-Hispanic Black. *p*-value: Computed using the first and second-order Rao-Scott corrections to the Pearson chisquared test for survey data.

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TABLE 3 Survey weighted multinomial regression of SHSe at homes and in vehicles among youth who have never used any form of tobacco—National Youth Tobacco Survey, 2020.

	SHSe in home				SHSe in vehicle			
	Moderate		Severe		Moderate		Severe	
	aOR	*p*-value	aOR	*p*-value	aOR	*p*-value	aOR	*p*-value
Age	0.9 (0.8–1.0)	0.14	0.9 (0.8–1.0)	0.09	1.0 (0.9–1.1)	0.89	1.0 (0.9–1.2)	0.61
Sex-sexual identity								
Male-heterosexual	Ref							
Female-bisexual	1.2 (0.7–2.1)	0.59	2.0 (1.2–3.4)	**0.01**	1.0 (0.6–1.7)	0.88	1.4 (0.7–2.7)	0.28
Female-gay or lesbian	1.1 (0.4–3.0)	0.78	2.4 (0.9–6.2)	0.08	1.0 (0.5–2.2)	0.99	1.2 (0.5–3.0)	0.63
Female-heterosexual	0.7 (0.6–0.99)	**0.02**	1.1 (0.9–1.4)	0.38	1.2 (1.0–1.5)	0.10	1.3 (0.9–1.8)	0.14
Female-not sure	0.6 (0.3–1.4)	0.24	1.0 (0.5–1.8)	0.97	1.2 (0.7–2.2)	0.43	1.4 (0.6–3.3)	0.40
Male-bisexual	0.7 (0.3–1.6)	0.40	0.8 (0.3–2.1)	0.67	1.7 (0.8–3.7)	0.18	2.2 (0.6–7.9)	0.21
Male-gay	1.3 (0.5–3.7)	0.56	1.8 (0.5–7.3)	0.38	2.4 (0.7–7.7)	0.14	2.7 (0.7–10.7)	0.15
Male-not sure	0.9 (0.5–1.9)	0.81	0.9 (0.5–1.8)	0.84	1.6 (0.9–3.0)	0.12	1.1 (0.5–2.5)	0.71
School type								
High School	Ref							
Middle School	1.0 (0.6–1.5)	0.87	0.7 (0.5–1.0)	0.07	1.0 (0.7–1.4)	0.83	1.1 (0.6–1.9)	0.77
Spoken language								
English	Ref							
Other than English	1.2 (0.9–1.6)	0.15	1.1 (0.9–1.4)	0.46	1.0 (0.8–1.2)	0.70	1.0 (0.7–1.4)	0.97
Race/Ethnicity and Tobacco use of co-inhabitants								
NHW & not living with tobacco user	Ref							
NHB & not living with tobacco user	2.1 (1.1–3.9)	**0.03**	5.1 (2.2–11.7)	**<0.001**	1.6 (1.0–2.6)	0.07	3.5 (1.5–8.0)	**0.005**
Hispanic & not living with tobacco user	1.5 (1.0–2.4)	0.06	1.7 (0.8–4.0)	0.17	1.3 (0.9–1.8)	0.16	1.1 (0.5–2.7)	0.75
Other & not living with tobacco user	0.7 (0.3–1.5)	0.33	1.9 (0.6–5.9)	0.23	0.9 (0.6–1.5)	0.71	0.5 (0.1–4.8)	0.55
NHW & living with combustible tobacco user	21.6 (14.8–31.6)	**<0.001**	98.6 (47.8–203.6)	**<0.001**	9.6 (7.3–12.6)	**<0.001**	33.2 (17.7–62.3)	**<0.001**
NHB & living with combustible tobacco user	36.3 (19.6–67.1)	**<0.001**	134.6 (63.8–284.0)	**<0.001**	14.7 (8.9–24.4)	**<0.001**	44.3 (19.3–101.6)	**<0.001**
Hispanic & living with combustible tobacco user	26.0 (16.8–40.5)	**<0.001**	68.7 (30.9–152.6)	**<0.001**	7.0 (4.4–11.2)	**<0.001**	22.5 (11.4–44.4)	**<0.001**
Other & living with combustible tobacco user	17.8 (10.9–29.0)	**<0.001**	93.5 (41.5–210.7)	**<0.001**	5.9 (3.7–9.5)	**<0.001**	18.3 (8.7–38.5)	**<0.001**

NHW, Non-Hispanic White. NHB, Non-Hispanic Black. Bold face indicates statistical significance at two-sided p-value ≤ 0.05. aOR, Adjusted Odds Ratio.

smoke-free policies, including in private homes and vehicles across all states, stricter enforcement, and comprehensive educational campaigns. Public housing authorities could collaborate with health organizations to provide technical assistance and incentives for property owners, further strengthening smoke-free regulations and protecting residents from the dangers of SHSe (13).

By December 31, 2023, 28 states and several U.S. territories, including American Samoa, the District of Columbia, and Puerto Rico, have introduced regulations limiting smoking in worksites, childcare, and personal vehicles. However, despite growing public support and the proven benefits of these laws, there is still inconsistency in their application across states. Furthermore, smoking

laws prohibiting smoking while children are around vary significantly, with some states protecting children under eight, while others protecting children up to age 18 (16).

Based on the high rates of SHSe observed in our study, we call for national legislation, similar to seat-belt laws, that prohibits smoking in private vehicles and homes where children are present. Standardizing these measures across states presents a challenge, which can be met through comprehensive public education promoting smoke-free households, including personal vehicles. Local and state governments and community organizations can work together to ensure consistent protection against secondhand smoke exposure, focusing on safeguarding children. Interactive health campaigns should engage the public through social media and community events, raising awareness about the dangers of secondhand smoke. Dynamic health warnings, including graphic health warning labels on tobacco products, can effectively communicate the risks of SHSe to children, encouraging smokers to adopt smoke-free behaviors in homes and vehicles when children are present. Additionally, smart detection devices can be used to monitor cigarette smoke levels in real-time and alert when exposure is detected, allowing for immediate action to mitigate the risk. Also, installing high-efficiency air purification systems in homes can significantly reduce secondhand smoke particles, reducing exposure to children.

Limitations

This study is subject to some limitations. The NYTS is a self-reported survey and is, therefore, subject to recall and nonresponse bias. Also, the exposure is not verified with nicotine biomarkers. However, the validity of self-reported tobacco product exposure has been high in other population-based studies (49, 50) and has also been shown to consistently correlate well with serum cotinine levels (51). Additionally, the NYTS data is representative of middle and high school students who attended private or public schools; however, the study sample does not include school dropouts, another potential high-risk group. Nevertheless, according to the US Census Bureau School Enrollment Data (52), approximately 94% of children aged 10 to 18 were enrolled in traditional schools in 2019. Furthermore, our study did not have access to data on certain potential confounders, such as family economic status, parental education, and child health conditions. The absence of such variables may limit the deeper understanding of factors associated with youth SHSe.

Future research should prioritize longitudinal studies to estimate the causal relationships between SHSe and long-term health consequences in vulnerable populations, such as sexual/gender minority youth and those living with tobacco product users, as this is a limitation of cross-sectional studies. Such longitudinal studies should incorporate objective measures of SHSe, like cotinine levels in saliva or urine, which are reliable biomarkers of nicotine exposure from secondhand smoke (53). Additionally, future research should focus on developing and evaluating targeted interventions to reduce SHSe in vulnerable populations, including educational programs, enhanced funding for smoking cessation, and policies promoting smoke-free private houses and vehicles. Assessing the impact of these interventions on reducing cotinine levels and improving health outcomes will be crucial for informing evidence-based public health strategies to protect vulnerable populations from the harmful effects of SHSe.

Conclusion

The study identified significant SHSe disparities among racial, sexual, and gender minority youth. Significant efforts are needed to develop targeted interventions to reduce SHSe in homes and vehicles, particularly in these vulnerable populations.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://www.cdc.gov/tobacco/data_statistics/surveys/nyts/index.htm.

Ethics statement

The Office of Management and Budget (OMB), ICF's Institutional Review Board (IRB), and CDC's Institutional Review Board (IRB) approved the NYTS cycles used in this study. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

RT: Conceptualization, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Software. SahS: Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. SurS: Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. SanS: Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing, Conceptualization, Funding acquisition, Project administration, Resources, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Is India on a path to reduce the tobacco industry's influence in tobacco control? Insights from the Global Tobacco Industry Interference Index (2019–2023)

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Introduction: The tobacco industry (TI), driven by profit motives, consistently conceals health risks through deceptive strategies, notably in countries like India. These tactics create vulnerabilities that hinder effective tobacco control measures and enable the TI to exploit legal gaps. Understanding these TI strategies is essential for policymakers to take appropriate preventive and corrective measures in order to limit tobacco industry interference (TII) in policy-making. The study aims at understanding the trend of TII in India between 2019 and 2023.

Methodology: The secondary data from the Global Tobacco Industry Interference report, consisting of seven major domains of the TII index, viz. policy participation, corporate social responsibility (CSR) activities, industry benefits, unnecessary interaction, transparency, conflict of interest, and preventive measures, were retrieved. A composite score was obtained after adding scores of different domains, for each year.

Results: The findings of the study demonstrated an initial improvement in India's implementation of WHO FCTC Article 5.3, as evidenced by a decreasing score between 2019 and 2021. However, this trend halted in 2023, with data showing a slight increase in the score. When compared with other Asian countries, India shows marginal improvement in score than Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, Philippines, Thailand, and South Korea. Some of the countries in the region, including India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Brunei, China, and Vietnam experienced a decline in TII.

Discussion: There has been a rise in CSR activities, forms of unnecessary interactions of TII with policymakers, and participation in policy development; however, improvements are observed in providing benefits to the TI, conflict of interest, and preventive measures. In order to fortify the regulatory framework, it is imperative to create awareness among stakeholders on conflict of interest, denormalize corporate social responsibility (CSR) initiatives by the TI, provision of a watchdog for TII in the country and "whole of government" approach in implementation of FCTC Article 5.3.

KEYWORDS

tobacco industry, WHO FCTC article 5.3, global tobacco industry interference, India, policy

Introduction

The consumption of tobacco products results in over 8 million fatalities annually, including 1.2 million deaths from exposure to second-hand smoke (1). Low- and middle-income countries, accounting for the majority (over 80%) of the world's 1.3 billion tobacco users, experience the heaviest impact of tobacco-related diseases and deaths. This burden is exacerbated by the fact that households often allocate essential funds meant for necessities such as food, shelter, and children's education, etc. toward tobacco consumption, leading to increased poverty levels (1). India faces a dual burden in the realm of tobacco consumption, encompassing both smoking and smokeless tobacco making tobacco control, a high priority in the country (2). According to the findings of the Global Adult Tobacco Survey (GATS), conducted in 2016–17, 28.6% of the adult population (42.4% men and 14.2% women) consumes tobacco in various forms (3). National Family Health Survey (NFHS-5) conducted between 2019 and 2021 had similar findings, suggesting that 38% of men consume tobacco, including 28.8% in urban and 42.7% in rural areas, while 8.9% of women consume tobacco including 5.4% in urban and 10.5% in rural areas (4). In addition to the negative effects smoking has on health, a WHO study confirmed the huge economic cost of tobacco-related illnesses and early deaths costs India 1% of its GDP (5). Moreover, the excise taxes on tobacco products yield a loss to the Indian economy of Rs. 816 for every Rs. 100 collected (5).

To maintain its profits and boost sales, the tobacco industry (TI) has always attempted to conceal the negative effects of tobacco consumption on health from the general public (6). Cigarette and smokeless tobacco companies invest billions annually in marketing their products (7, 8). In India, the tobacco products market is anticipated to generate $13,370 million in revenue in 2024, with an annual growth rate of 4.41% from 2024 to 2029 (9). The industry employs approximately 7.25 million people (10) and exported $923.80 million worth of tobacco products in 2021–2022 (11). The TI deploys deceptive strategies exploiting key areas of economic activity, marketing/promotional action, and political activity, and through its manipulative behavior in low- and middle-income countries, including India (12). For instance, Godfrey Philips provided support to flood-affected vendors in Srinagar in the year 2014, creating a deceptive image of being a socially responsible brand (12). Other countries, a fundamental and unresolvable clash exists between the TI's priorities and public health policies in India (13). The TI has been a significant barrier, undermining the nation's efforts to implement tobacco control laws. For instance, the TI lobbied for watering and delaying the decision to implement 85% pictorial health warnings (PHWs) in India (14). In another instance, the TI used various strategies to persuade lawmakers and front groups to postpone and divert their attention from the proposed Cigarettes and Other Tobacco Products (Prohibition of Advertisement and Regulation of Trade and Commerce, Production, Supply, and Distribution) Act, COTPA (Amendment) Bill, under the assumption that the amended act would have a detrimental effect on the bidi industry and farmers in the certain states (15). TI in India spends so-called CSR money on primary education, sanitation initiatives, and health promotion initiatives (16–18). In accordance with various government programs at the federal and state levels, the TI also supports agriculture, solid waste management, women's empowerment, health and sanitation programs, and overall development (16). The initial initiatives by the MoHFW to outlaw ENDS under the Drugs and Cosmetics Act were thwarted by legal challenges and state orders (19). The multinational ENDS giants also provided funding to local ENDS importers to fight the ordinance in court before the country-level ordinance, namely the Prohibition of Electronic Cigarettes Act, 2019 (PECA) was enforced in India (20).

According to Section 135 of the Indian Companies Act, 2013, all companies, including private and limited ones, must spend 2% of their Profit After Tax (PAT) on CSR if they meet any of these criteria: a net worth of Rs. 500 crores or more, a turnover of Rs. 1,000 crores or more, or a net profit of Rs. 5 crores or more. The 2% CSR expenditure is calculated based on the average PAT of the last three financial years (21). FCTC recommends banning TI CSR activities to de-normalize and regulate their so-called "socially responsible" actions (22). During the COVID-19 outbreak, several tobacco companies cumulatively committed approximately US$36.7 million in donations to various government funds, including the "Prime Minister's Citizen Assistance and Relief in Emergency Situations Fund" (PM CARES Fund) of the Government of India and the Chief Minister's Relief Fund of different State Governments in the country (23).

The Government of India has ratified the WHO FCTC (21) that outlines important strategies for lowering demand and raising the supply of tobacco, in 2004 (24). Article 5.3 of FCTC aims at safeguarding the policy-making process from the commercial and vested interest of the TI. It seeks to overcome obstacles that hinder the effective implementation of the convention by addressing the issue of TI's political activities (25). In addition to this, India has undertaken several initiatives, including a lack of specific COTPA enforcement (26), 85% PHW (27), ENDS (Electronic Nicotine Delivery Systems) ban (28), tobacco-free educational institutions guidelines (29), and implementation of the world's largest national tobacco quitline (30).

On 24 June 2019, the Indian Ministry of Health and Family Welfare issued a letter, signed by Additional Secretary Sanjeeva Kumar, to all state governments in India that emphasized India's commitment under the WHO FCTC Article 5.3 (31). It cautioned against any collaboration with the Foundation for Smoke-Free World (FSFW), funded by Philip Morris International (PMI), in the interest of public health (31). FSFW and PMI advocate for alternative devices such as e-cigarettes under the guise of promoting a "smoke-free but not vape-free" world (31). The letter also referenced the WHO FCTC Secretariat's statement, characterizing FSFW as a blatant attempt to undermine the FCTC by interfering in public policy, aimed at undermining treaty implementation (31). These stances reflect the political will to prioritize public health over industry interests. However, the country faces a number of challenges in limiting the influence of the TI, including a lack of specific provisions to deal with industry interference under COTPA 2003, insufficient efforts to implement Article 5.3 of WHO FCTC, influence over policymakers, lack of awareness among policymakers within and outside the health sector, lack of public support, sophisticated marketing strategies adopted by TI, absence of political will, complex legal processes, and international trade benefits (India is the second largest exporter of tobacco after Brazil) (32). These vulnerabilities prevent tobacco control measures from being implemented and monitored effectively and also provide the business room to take advantage of legal weaknesses and work around restrictions. An understanding of the trend of tobacco industry interference (TII) in India will help

policymakers and implementors in determining the areas that need additional support in safeguarding public health from the overall detrimental effects of tobacco. The current study uses the Global Tobacco Industry Interference Index to investigate the trend of TII in India between 2019 and 2023.

What is already known on this topic

The tobacco industry (TI) is known to conceal the harmful effects of tobacco use from the public and use tactics to influence public policies related to tobacco for commercial gains. An extensive tool namely Global Tobacco Industry Interference Index exists which assesses the level of tobacco industry influence by measuring the Implementation of Article 5.3.

What is unknown on this topic

How exactly (using specific tactics) TI interferes in tobacco control over time in India and what has been government response over time. Understanding and analysing TI strategies along with government response is essential for policy makers to take appropriate preventive and corrective measures in order to limit TII in policy making.

Policy implications

The findings will help policymakers improve their approaches and bolster their efforts to prevent/minimise TII to safeguard public health.

Methods

The current study utilizes a comprehensive global dataset to assess TII in India and across Asian countries. The data come from the Global Tobacco Industry Interference Index, an annually updated resource that has expanded its coverage over time.

Data source

The secondary data originated from the four rounds of the Global Tobacco Industry Interference Index; the first index in 2019 encompassed 33 countries, followed by the second index in 2020 covering 57 countries, and subsequently the third index in 2021 covering 80 countries and fourth index in 2023 evaluating 90 countries. The country's ranking was executed using the identical questionnaire and scoring approach as the ASEAN Index, devised by the Southeast Asia Tobacco Control Alliance (33). The Global Center for Good Governance in Tobacco Control (GGTC), situated at the School of Global Studies, at Thammasat University, acts as the leading center with support from Stopping Tobacco Organizations and Products (STOP), Thai Health Promotion Foundation, and the Bill and Melinda Gates Foundation (facilitates the assessment of countries and the formulation of the index) (34), which assists in assessing countries and formulating the index. The index is based upon a publicly accessible dataset concerning TII within countries, as well as the responses of their respective governments and civil society organizations about the domains of the index to such interference (34).

Study variables

The Global Tobacco Index (or Global Tobacco Industry Interference Index) rates a nation according to how governments address the industry, incorporating preventative measures (34). The seven major domains of the index are Participation in Policy Development, Tobacco-Related CSR Activities, Benefits to Tobacco Industry, Forms of Unnecessary Interaction, Transparency, Conflict of Interest, and Preventive Measures (34–37).

Data analysis

A composite score was obtained after adding the scores for various domains of the Global Tobacco Industry Interference Index for each year. A lower score indicates a reduced level of overall interference, which is considered beneficial for the country's public health efforts (34).

Ethics considerations

The study relies on publicly available secondary data, eliminating the need for informed consent. Data privacy and confidentiality are ensured by utilizing aggregated information. Since no direct interaction with human participants took place, the study does not involve potential harm to individuals.

Results

A total of 33, 57, 80, and 90 nations were represented in the first (2019), second (2020), third (2021), and fourth (2023) rounds of the Global Tobacco Index report respectively. The TI's involvement in policy development in India has been on the rise, increasing from a score of 6 in 2019 to a consistent 7 in 2020, 2021, and 2023. The industry's involvement takes the form of advisory groups in public health policy and exhibits an increase from three points in 2019 to five points in 2020, 2021, and 2023. The score of tobacco-related CSR initiatives as per Recommendation 6.2 (The government agencies/officials endorse, form partnerships with/participate in TI CSR activities) also increased from 4 in 2019 and 2020 to 5 in 2021 and 2023. The government's support for the TI, as outlined in Recommendation 7.3 (The government gives privileges, incentives, exemptions, or benefits to the TI), has consistently held at a score of five for three consecutive years and has experienced a decrease to four points in the year 2023. The level of interaction between the industry and the government has shown a fluctuating pattern, beginning at 12 in 2019, dropping to 9 in 2020, rebounding to 11 in 2021, and further increasing to 14 in 2023. Transparency in government interactions with the industry has decreased, falling from 9 in 2019 to 10 in both 2020 and 2021, and further declining to 9 in 2023. Meanwhile, the score for conflict of interest has

consistently dropped from 12 in 2019 to 10 in 2020 and has been a consistent 9 in 2021, and 2023. Notably, preventive measures demonstrated significant improvement over the 5-year span, plummeting from a rating of 21 in 2019 to 10 in 2021 and remaining the same in 2023.

Throughout the 5-year period, India's overall score consistently reflects an improving trend, beginning at 69 in 2019, declining to 61 in 2020, further decreasing to 57 in 2021, and ultimately settling at 58 in 2023. The reduction of scores in the preventative measures was done through increased transparency in its dealings with the TI (Recommendation 5.1), implementing a code of conduct for public officials when dealing with the TI (Recommendation 4.2), by asking the TI to disclose information on tobacco production and manufacturing and other activities including lobbying, philanthropy, and political contributions periodically (Recommendation 5.2) (Table 1).

The implementation of Article 5.3 in the Asian region exhibits an irregular trend, as demonstrated by the scores obtained from the Global Tobacco Industry Interference Index for the years 2019–2023. Several countries, including India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Brunei, China, and Vietnam, have demonstrated improvements in their scores. Conversely, countries such as Cambodia, China, Indonesia, Lao PDR, Malaysia, Nepal, the Philippines, Thailand, and South Korea have seen declines in their performance. The overall trends depict varied efforts in tobacco control across the region, with some countries making progress and others facing challenges (Figure 1).

Discussion

The current study employs the Global Tobacco Industry Interference Index to evaluate trends in TII in India. The findings of the study demonstrated an initial improvement in India's implementation of WHO FCTC Article 5.3, as evidenced by a decreasing score between 2019 and 2021. However, this trend halted in 2023, with data showing a slight increase in the score.

Participation in policy development

Despite being a signatory to the convention for 15 years, India has not been able to establish a national policy for all government officials that effectively prevents interference from the TI (38). Many countries such as Iran, Korea, Nepal, Kenya, the UK, Uganda, and Uruguay have set commendable examples by excluding the TI from policy-making discussions and rejecting any form of support, collaboration, or input from the industry when developing and implementing public health policies (36, 38, 39). In India, though the TI is not part of policy development, indirect lobbying efforts and political favors influence the policy (40). In addition, health is a state subject in India, so many state governments have taken proactive initiatives to control the interference of the TI. For example, the High Court of Karnataka demanded the Tobacco Board of India to withdraw its participation and funding from a TI event, in addition to asking governments to consider a "code of conduct" for dealing with the TI (41). To date, 22 states of India have enacted a protocol for public employees, banning the exchange of favors or any cooperation between a public agency and the tobacco business, hence limiting the interactions between public officials and the TI (42).

Tobacco-related CSR activities

India's corporate sector, including cigarette corporations, is mandated to allocate a minimum of 2% of profits to corporate social responsibility (CSR) activities under the Companies Act if the net worth of the company is more than 500 crore or their annual turnover is above 1,000 crores or the net profit is above 500 crores (43). As this rule also applies to some cigarette companies, a challenging situation has emerged because the social welfare initiatives of these companies may indirectly encourage tobacco use. To manage this shortcoming in the Companies Act, both the Cigarettes and Other Tobacco Products Act (2003) and FCTC recommend banning TI CSR activities to de-normalize and regulate their so-called "socially responsible" actions (22). The government has witnessed a gradual rise in the contributions received from the TI, and an increase in collaborations between the government and the industry for CSR initiatives over time (23). In one of the instances Indian tobacco businesses contributed close to US$37 million to government coffers as part of COVID-19 relief initiatives (23), for enhancing their corporate image and generating profits, thereby contravening the provisions under COTPA 2003 and FCTC Article 5.3. These CSR activities conducted by Indian tobacco companies involve the utilization of their corporate trademarks, which are also present on their respective tobacco products. As a case in point, ITC employs the "ITC" trademark across all its tobacco and non-tobacco goods, while "Godfrey Phillips" and "DS Group" employ the same trademark for their entire product range. These instances of CSR activities conducted by Indian tobacco companies, especially the usage of company trademarks, violate not only Section 5(3)(b) of COTPA 2003 but also Article 13 of the WHO Framework Convention on Tobacco Control (WHO FCTC) and the associated implementation guidelines (12, 23). For example, in response to a legal petition, one of the high court of India has categorically outlined that the cigarettes and TI, in the course of their CSR activities, cannot breach the provisions outlined in the COTPA, 2003 (44).

Benefits to the tobacco industry

WHO Article 5.3 demanded that the countries should refrain from providing advantages or incentives to the TI (36). In the countries, where CSR activities were reportedly intensive such as Malaysia, Pakistan, Tanzania, and Zambia, it was observed that these countries did not impose any tax increases on tobacco (36). In a similar fashion, India was unable to make progress in ceasing the provision of benefits to the TI, as evidenced by a consistent score of five points maintained between 2019 and 2021. The evidence suggests that the Indian government continues to grant privileges, incentives, exemptions, or benefits to the TI (34–36). However, there has been improvement in the period from 2022 to 2023, with the score decreasing to four. The introduction of India's Goods and Services Tax (GST) in 2017 brought about substantial changes to the system of indirect taxation. All tobacco products became subject to the highest slab (28% GST) with an additional

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TABLE 1 Trend analysis using the global tobacco industry interference index from 2019 to 2023 in India.

Parameters of assessment	Maximum possible score	Year of assessment			
		2019	2020	2021	2023
Participation in policy development	20	6	7	7	7
The government accepts, supports, or endorses offers for assistance by or in collaboration with the tobacco industry in implementing tobacco control policies (Recommendation 3.1)	5	2	1	1	1
The government accepts, supports, or endorses legislation drafted by/in collaboration with the tobacco industry (Recommendation 3.4)	5	0	0	0	0
The government allows the tobacco industry to sit in multi-sectoral committee/advisory group that sets public health policy (Recommendation 4.8)	5	3	5	5	5
The government allows representatives from the tobacco industry (including State-owned) in the delegation to the COP or subsidiary bodies or accepts their sponsorship for delegates. (Recommendations 4.9 and 8.3)	5	1	1	1	1
Tobacco related CSR activities	5	4	4	5	5
The government receives contributions from the tobacco industry (including so-called CSR contributions) (Recommendation 6.4) The government agencies/officials endorse, form partnerships with/participate in tobacco industry CSR activities (Recommendation 6.2)	5	4	4	5	5
Benefits to the tobacco industry	10	5	5	5	4
The government accommodates requests from the industry for longer implementation time or postponement of tobacco control law (Recommendation 7.1)	5	0	0	0	0
The government gives privileges, incentives, exemptions, or benefits to the tobacco industry (Recommendation 7.3)	5	5	5	5	4
Forms of unnecessary interaction	15	12	9	11	14
Top-level government officials meet with/ foster relations with the tobacco companies such as attending social functions and events sponsored or organized by the tobacco companies (Recommendation 2.1)	5	3	2	3	5
The government accepts assistance/offers of assistance from the tobacco industry on enforcement (Recommendations 3.1 and 4.3)	5	5	3	4	4
The government accepts, supports, endorses, or enters into partnerships or agreements with the tobacco industry (Recommendation 3.1)	5	4	4	4	5
Transparency	10	9	10	10	9
The government does not publicly disclose meetings/ interactions with the tobacco industry where such interactions are strictly necessary for regulation (Recommendation 2.2)	5	5	5	5	5
The government requires rules for the disclosure or registration of tobacco industry entities, affiliate organizations, and individuals acting on their behalf including lobbyists.	5	4	5	5	4
Conflict of interest	15	12	10	9	9
The government does not have a policy (whether or not written) to prohibit contributions from the tobacco industry or any entity working to further its interests to political parties, candidates, or campaigns or to require full disclosure of such contributions (Recommendation 4.11)	5	4	5	4	4
Retired senior officials work for the tobacco industry (Recommendation 4.4)	5	4	5	5	5
Current government officials and their relatives hold positions in the tobacco business including consultancy positions (Recommendations 4.5, 4.8, and 4.10)	5	4	0	0	0
Preventive measures	25	21	16	10	10
The government has a procedure for disclosing records of the interaction with the tobacco industry and its representatives (Recommendation 5.1)	5	4	4	2	2
The government has formulated, adopted, or implemented a code of conduct for public officials, prescribing the standards they should comply with when dealings with the tobacco industry (Recommendation 4.2)	5	4	4	2	2
The government requires the tobacco industry to periodically submit information on tobacco production, manufacture, market share, marketing expenditures, revenues, and any other activity, including lobbying, philanthropy, and political contributions (Recommendation 5.2)	5	5	2	2	2
The government has a program/system/plan to consistently raise awareness within its departments on policies relating to FCTC Article 5.3 Guidelines (Recommendation 1.1 and 1.2)	5	3	2	2	2

(Continued)

TABLE 1 (Continued)

Parameters of assessment	Maximum possible score	Year of assessment			
		2019	2020	2021	2023
The government has a policy prohibiting the acceptance of all forms of contributions from the tobacco industry (monetary or otherwise) including offers of assistance, policy drafts, or study visit invitations to the government, officials, and their relatives (Recommendation 3.4)	5	5	4	2	2
Total	100	69	61	57	58

compensation cess for cigarettes and smokeless tobacco products (45). However, for some states, the newly introduced taxes were less as compared to the old VAT regime (45). Moreover, the beedi (hand-rolled tobacco wrapped in specific tendu leaves) industry enjoys the status of a cottage industry and remains out of this tax slab. Furthermore, companies with <20 employees or small tobacco farmers and exporters are also exempted from tax (40). Such exemption should be withdrawn and uniform taxation should be introduced to all tobacco products in line with WHO recommended taxation of 75% on the retail price of tobacco products (46).

Forms of unnecessary interactions

Unwarranted engagements take place when high-ranking government officials attend social events organized by tobacco companies or when the government embraces offers of assistance or forms partnerships with the TI (34). The TI has gained notoriety for its resourcefulness in maintaining relationships with governments worldwide (47). In 2015, India's largest cigarette manufacturer provided funding for the 10th Sustainability Summit held in the capital city of New Delhi (47). This tobacco company has a long-standing association with the CII-ITC Center of Excellence for Sustainable Development, which regulates these events with partnerships with various government ministries, including Housing and Urban Poverty Alleviation and Environment, Forests and Climate Change, and GIZ (German Society for International Cooperation, Ltd.) (47). Few prominent figures from the TI often held key positions in these summits, frequently alongside policymakers. A representative from the United Nations Development Program (UNDP) was also listed as a speaker (47). This summit evoked memories of the World Business and Development Awards, an initiative supported by UNDP to recognize private sector entities striving to achieve the Millennium Development Goals (47).

Transparency

The significance of transparency is emphasized in WHO Article 5.3, which urges governments to establish mechanisms that mandate the TI to provide regular disclosures regarding their activities and practices. However, the government falls short of ensuring such obligations from the TI, as evident from the rise in the overall score from nine in 2019 to 10 in both 2020 and 2021. Additionally, there has been a rise in the score from four in 2019 to five in both 2020 and 2021, followed by a decline to four in 2023 regarding the need for the government to implement rules regarding the disclosure or registration of TI entities, affiliate organizations, and individuals acting on their behalf, including lobbyists (34–37).

Conflict of interest

The guidelines outlined in Article 5.3 recommend the avoidance of conflicts of interest among government officials and employees, along with the establishment of rules to safeguard public health policies from interference by the TI (34). To prevent industry influence on tobacco control policies and programs, India's Ministry of Health and Family Welfare adopted a code of conduct in 2020 after 13 states implemented Article 5.3; however, the scope of application is restricted to health ministry officials (48). A former member of the Indian Administrative Service (IAS) who held several high-level positions in the Ministries of Communications, Information Technology, and Home Affairs in India has joined the Godfrey Philips board as an independent director (49). A former Honorable President of India was the chief guest at the Confederation of Indian Industry (CII)-ITC Sustainability Awards event in 2012, which presents a conflict of interest (13). Furthermore, in 2011, the Chairman of one large tobacco company was bestowed with the Padma Bhushan, which is India's third highest civilian award, thereby highlighting a possible contradiction between their official positions and their associations with the TI (13). Over the course of 5 years, the Indian government has demonstrated progress in addressing conflicts of interest, as reflected in the decrease in scores from 12 in 2019 to 10 in 2020 and further to 9 in 2021 and 2023.

Preventative measures

The guidelines outlined in Article 5.3 offer a variety of measures that governments can implement to safeguard their tobacco control policies against interference from commercial and vested interests (36). The adoption of a code of conduct for officials dealing with the TI, the implementation of transparency and accountability procedures for interactions, and the prohibition of accepting any kind of contributions—including technical assistance—from the TI are just a few proactive steps that governments can take to protect their officials from exposure to interference (39). Several nations, including the Philippines, the United Kingdom, and Australia, have implemented a code of conduct guiding public official's interactions with the TI. Following them in July 2020 India has also embraced a similar code of conduct for public officials engaging with the TI (50). This indicator showed the most improvement among all indicators over a 5-year period, reducing from a score of 21 in 2019 to 10 in 2023. However, the national policy, titled "Code of Conduct for Public

Officials," applies only to officials of the Ministry of Health and Family Welfare, limiting its scope (51). This restriction contradicts Article 5.3 guidelines, creating a barrier to effective implementation (13). A broader national policy is needed, aligning with state initiatives, to establish effective multilevel governance for tobacco control (13). Despite the fact that various states have codes of conduct for dealing with public officials across the government; however, they are limited in their implementation and are variable, which are not fully compliant with a recommendation under WHO FCTC Article 5.3 (52).

Despite laudable efforts by India over the last few decades to improve TII scores, there have been increasing rates of cancers. The etiology of cancer is quite complex and is driven by multiple variables including demographic, social, economic, and cultural factors. Effective tobacco control measures usually show their positive impact on cancer incidence only after a decade or more. Therefore, it is not unusual to see enhanced tobacco control measures coexisting with increasing cancer incidence and current prevalence rates. Factors such as age, alcohol consumption, exposure to carcinogens, chronic inflammation, diet, hormonal changes, immunosuppression, infectious agents, obesity, radiation, and sunlight exposure all contribute to the multifaceted nature of cancer risk, highlighting that focusing solely on tobacco control may not be sufficient to reduce overall cancer rates (53). However, accelerated tobacco-control programs, especially in areas where usage is increasing, will be crucial in reducing the rates of tobacco-related cancer mortality (54).

The top tobacco companies operating in India ITC, British American Tobacco's Indian affiliate, Godfrey Phillips India holds a dominant 90% share of the Indian manufactured cigarette market (55, 56). These figures indicate significant market power and revenue for these companies (55, 56). Historically, Indian tobacco companies spent heavily on marketing and advertising before restrictions, demonstrating substantial financial resources. During the COVID-19 pandemic, tobacco companies made significant donations and CSR contributions, contributing approximately $36.7 million (23). ITC alone committed $13.2 million to the PM CARES Fund and established a $19.8 million contingency fund, reflecting their considerable financial capability (23). Moreover tobacco companies have also continued to influence the government through sponsorship and CSR activities, as highlighted in the India Tobacco Industry Interference Index 2020, indicating their financial capacity to engage in policy-influencing activities.

In the regional context, India's scores positioned it mid-way, akin to countries such as Pakistan, Vietnam, and the Philippines. Another group of countries, including Thailand, Nepal, Sri Lanka, and Maldives exhibited lower scores (41–50) than India demonstrating a significant improvement in implementation of Article 5.3 of FCTC. Conversely, a cluster of significant economies, including Malaysia, Bangladesh, Lao PDR, China, Indonesia, and Japan, registered higher scores than India (70–88). Notably, India and Sri Lanka made commendable progress, with scores dropping from 69 to 58 and 58 to 42, respectively.

Limitations

The current study draws patterns from the Global Tobacco Industry Interference Index which only includes data that is readily accessible to the public limiting its scope (36). A major limitation is the reliance on publicly available information. In a country like India, which is vast, multilingual, and has numerous media outlets, as well as many business and government entities operating at various levels and scales, it is challenging to gather and scrutinize all potential evidence of TII present in the public domain. For example, many studies on TII in India have only examined English-language media and have only marginally considered selected regional language media. This limitation is particularly significant in India's complex landscape. Due to its vast size,

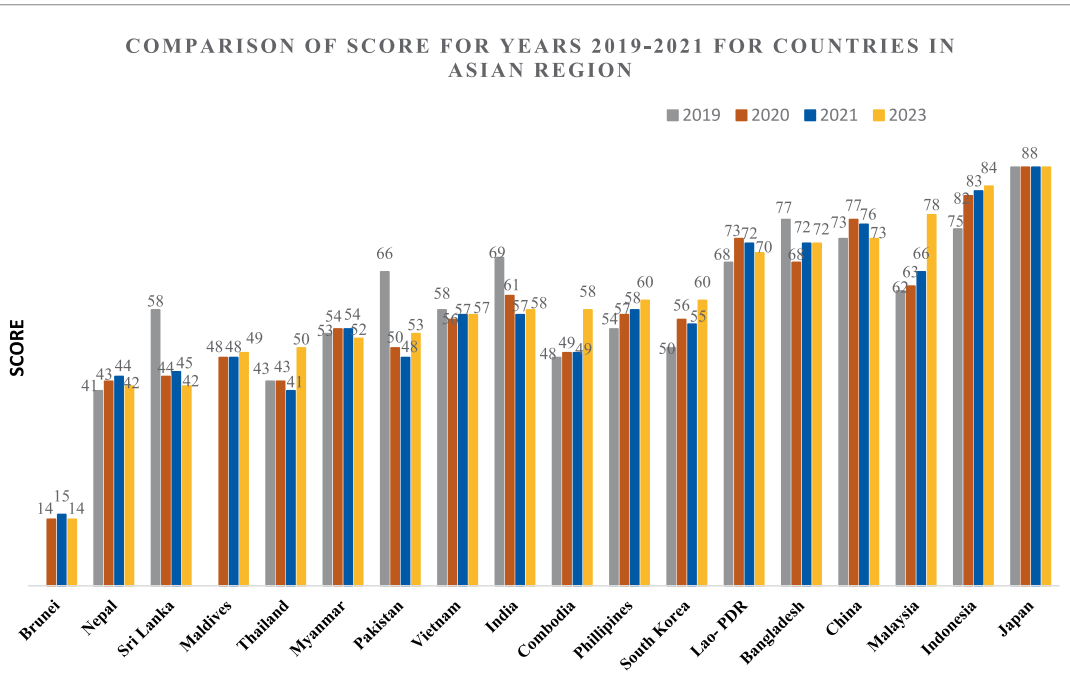

FIGURE 1
Comparison of global TII scores for 3 years (2019–2021) for countries in the Asian Region.

linguistic diversity, numerous media outlets, and many business and government entities, comprehensively gathering and analyzing all potential evidence of TII is extremely challenging. Many Indian TII studies have primarily focused on English-language media, with only limited exploration of regional language sources. It is challenging to gather comprehensive data on industry interference, which is a crucial provision of the FCTC rules because of a lack of transparency. Some of the TI's interference and lobbying activities would have become virtual with the introduction of pandemic-related lockdowns and movement restrictions in many countries, making them less transparent and more difficult to monitor and document (36). Furthermore, the global index provides aggregate scores at the indicator level. In addition, it is limited regarding access to specific TII instances and/or examples of preventive measures scored in order to arrive at indicator-level scores. The lack of such granular-level insights limits us in making more specific recommendations/interpretations.

Conclusion

It is essential that India should develop a national policy specifically designed to prevent TII, as a standalone policy or embedded in the prevailing national tobacco control legislation (COTPA). This policy should be uniformly applicable and enforceable across all departments/agencies across national government and governments in every state and union territory. Further raising awareness among non-governmental organizations, governmental institutions, development sector partners, and elected leaders about TII and measures to prevent the same is of paramount importance. The establishment of a dedicated watchdog entity to monitor the TI's activities, particularly its attempts to influence policy agenda-setting and implementation, is crucial, and so are the measures for the protection of whistle-blowers.

In addition to this, it is essential to go beyond the existing code of conduct for public officials and address structural and policy-level conflicts, such as those arising from the mandate of the Tobacco Board of India or investments by Public Sector Undertakings (PSUs) in the TI, bringing policy coherence across different government agencies in the interest of public health. Policymakers should also prioritize efforts to denormalize and prevent the so-called CSR by the TI that currently seems to promote the industry's social image and access to decision-making space. Instead, such mandatory financial contributions from the industry could be directed by governments toward tobacco control-related activities, while ensuring that their CSR and/or environmental, social, and governance (ESG) activities are not exploited for publicity gains.

Strengthening the mechanisms for implementing and enforcing tobacco control policies is critical to ensure that improved TII scores translate into reduced industry interference in tobacco control and correspondingly stronger and effective tobacco control measures leading to positive health impacts. Increased support for research examining the long-term impact of tobacco control policies is essential to bridge the gap between policy implementation and health outcomes. Finally, bolstering cooperation with other countries and international organizations to share best practices and strategies in combating TII should be a key priority.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SG: Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. DW: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. UB: Investigation, Supervision, Writing – original draft, Writing – review & editing. NB: Methodology, Writing – original draft, Writing – review & editing. MC: Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Vendor density mapping and compliance assessment with tobacco control laws around schools in Bhubaneswar City—a geo-spatial mapping and observational study

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Background: Tobacco use among youth remains a significant public health challenge, particularly in India, where vendor accessibility plays a crucial role in initiation and consumption. This study examines tobacco vendor density around schools in Bhubaneswar City, Odisha, utilizing advanced geo-spatial mapping techniques to provide evidence for regulatory enforcement.

Methods: A geo-spatial mapping approach was employed using ArcMap 10.8 and Google Maps to identify tobacco vendors within a 100-yard radius of 15 selected high schools. Data collection was conducted through a structured questionnaire with 53 closed-ended questions via the Epicollect5 platform. The study adopted a probability proportional-to-size sampling method to ensure representative vendor distribution.

Results: The study identified 107 tobacco vendors surrounding the selected schools, with an average vendor density of approximately seven per school vicinity. Pan vendors and grocery/convenience stores were the most prevalent vendor types. Despite existing regulations, widespread tobacco advertising, brand displays, and promotional activities were observed. Additionally, violations related to smoking near schools and sales to minors indicated gaps in regulatory compliance.

Conclusion: The high density of tobacco vendors near schools underscores the need for strengthened enforcement mechanisms and policy interventions. Enhancing regulatory compliance through stricter zoning laws, targeted monitoring, and community-driven initiatives is essential to reducing youth exposure to tobacco products and mitigating associated health risks.

KEYWORDS

tobacco control, geo-spatial mapping, vendor density, COTPA Act, compliance

1 Introduction

Tobacco use among youth and children remains a pressing global public health crisis with far-reaching consequences (1). According to global estimates, one in every 10 girls and one in every five boys aged 13–15 years use tobacco (2). While tobacco consumption affects individuals of all ages, initiating use during childhood and adolescence is particularly detrimental, increasing the risk of long-term addiction, chronic diseases, and premature mortality (3). Its widespread use is a leading contributor to preventable death and disease, spanning a spectrum of chronic conditions such as cancer, respiratory ailments, cardiovascular disorders, and stroke (3).

Recognizing its detrimental effects, the World Health Organization (WHO) identifies tobacco use as a major risk factor for non-communicable diseases (NCDs), responsible for an estimated 8 million deaths annually (4, 5). This epidemic affects individuals of all ages and socioeconomic backgrounds, with a disproportionate impact on low- and middle-income countries (LMICs), where tobacco control measures may be less robust and more aggressive industry tactics (4, 6).

India, one of the world's largest consumers of tobacco, faces an immense burden of tobacco-related morbidity and mortality. With nearly 267 million adult tobacco users, the country accounts for a significant share of global tobacco consumption (7). The prevalence of both smoking and smokeless tobacco products—such as cigarettes, bidis, hookah, khaini, gutkha, betel quid with tobacco, and zarda—makes tobacco control particularly complex (8). Of particular concern is the early initiation of tobacco use among Indian youth. Data from the Global Youth Tobacco Survey (GYTS) 2019 reveals that 38% of cigarette smokers, 47% of bidi smokers, and 52% of smokeless tobacco users in India began using tobacco before the age of 10. The median age at initiation for cigarette and bidi smoking was 11.5 years and 10.5 years, respectively, highlighting early onset of tobacco use. Additionally, nearly one-fifth of students aged 13–15 reported using some form of tobacco product in their lifetime, with a current usage rate of 8.5% in the last 30 days (9). These statistics emphasize the need for effective tobacco control measures to address early initiation and prevent tobacco use among youth. Early initiation of tobacco use is a risk factor for long-term addiction and adverse health consequences, emphasizing the need for targeted interventions to protect youth and children (10). Tobacco vendor density plays a crucial role in shaping tobacco consumption patterns, particularly among youth. Studies indicate that a high concentration of tobacco vendors near schools increases exposure and accessibility to tobacco products, significantly influencing initiation and continued use among students (11). Vendor clustering in school zones normalizes tobacco use, making it more socially acceptable and easier for minors to obtain tobacco products despite regulatory restrictions. Evidence from international and national research suggests that reducing vendor density near educational institutions can effectively lower youth smoking rates and prevent early initiation (11, 12).

Despite existing tobacco control laws, tobacco vendor density remains a largely under-researched aspect of youth tobacco prevention in India. Many studies focus on individual behavior, school-based interventions, or advertising restrictions, but fewer address how vendor proximity influences youth access and experimentation with tobacco (13). This study seeks to address this gap by systematically examining the density of tobacco vendors around schools in Bhubaneswar, Odisha. Understanding the geographical clustering of vendors can help policymakers strengthen zoning laws, restrict tobacco sales near schools, and implement targeted enforcement strategies.

Odisha, situated in eastern India, faces unique challenges regarding tobacco control. Data from the Global Youth Tobacco Survey (GYTS) 2019 reveals concerning prevalence rates of tobacco use among students in Odisha, with smokeless tobacco being the predominant form of consumption (14). Additionally, accessibility to tobacco products through tobacco vendors and exposure to tobacco advertising at points of sale present significant obstacles to effective tobacco control efforts in the state. Tobacco vendor density in Odisha remains high, with limited studies exploring its direct impact on youth tobacco use, making this an important area for research.

The Cigarettes and Other Tobacco Products Act (COTPA), enacted in 2003, serves as India's primary tobacco control legislation, imposing restrictions on tobacco sales, advertising, and consumption in public places (15). COTPA includes key provisions such as Section 4 (prohibiting smoking in public places), Section 5 (banning tobacco advertising and promotion), and Section 6 (restricting tobacco sales to and by minors). However, compliance with these regulations remains suboptimal, particularly around educational institutions where students are highly vulnerable to tobacco exposure (16, 17). Weak enforcement of COTPA provisions allows the continued operation of tobacco vendors near schools, counteracting efforts to protect youth from early tobacco initiation.

The implementation of Tobacco-Free Educational Institution (TOFEI) guidelines has been pivotal in reducing tobacco use among students. A study in Maharashtra demonstrated that schools with trained teachers showed higher compliance with TOFEI criteria, leading to a significant decrease in tobacco consumption among students (18). Similarly, research in Puducherry revealed that schools adhering to TOFEI guidelines had reduced evidence of tobacco use on premises, highlighting the guidelines' effectiveness in promoting a tobacco-free environment (19). These findings emphasize the importance of strict enforcement and regular monitoring of TOFEI guidelines to safeguard youth from tobacco exposure. Despite these efforts, vendor density around schools continues to undermine the effectiveness of COTPA and TOFEI policies, necessitating a comprehensive strategy that integrates vendor regulation with school-based interventions.

The study aims to map tobacco vendor density around 100-yard (91.44 meters) radius of schools and assess compliance with tobacco control laws in Bhubaneswar City, Odisha, India. By fulfilling these objectives, the study endeavors to provide valuable insights for informing evidence-based to support stricter zoning regulations and targeted interventions, ultimately contributing to more effective tobacco control policies for protecting youth.

2 Materials and methods

2.1 Study design and sampling

This cross-sectional observational study, conducted as part of a doctoral research, aimed to evaluate tobacco vendor density and compliance with tobacco control laws within schools and their proximity areas in Bhubaneswar, Odisha, India, from November 2023

to January 2024.Geographically, Bhubaneswar is divided into three zones by the Bhubaneswar Municipal Corporation (BMC): north, southeast, and southwest (20). From a pool of 65 high schools listed under the Department of School and Mass Education, Government of Odisha (21), 15 high schools were selected as part of doctoral research. High school in India refers to classes 8–10 (Figure 1).

The selection was made using the probability-proportional-to-size (PPS) sampling method to ensure a representative sample aligned with the study's precision and confidence level requirements, from a total of 65 high schools and a student population of 24,071. The sample size selection process was based on a formula utilizing a 95% confidence level, ±1.24% margin of error, and a prevalence of tobacco use in Odisha of 6.2% according to the Global Youth Tobacco Survey (GYTS), employing the P/5 approach for precision. Ethical clearance for the study was obtained from the institutional ethics committee of Siksha "O" Anusandhan, deemed to be University, Bhubaneswar, Odisha India, (Ref: Letter No.: Ref. No./DMR/IMS.SH/SOA/2021026).

2.2 Data collection and instrument

The identification of tobacco vendors within a 100-yard radius of the selected high schools was facilitated using advanced mapping software, namely ArcGIS version 10.8, complemented by Google Maps and satellite imagery to pinpoint significant landmarks and roads. Vendor selection criteria were formed by the types identified in the Global Youth Tobacco Survey (GYTS) (14), Global Adult Tobacco Survey (GATS) (22, 23) and insights from local stakeholders, encompassing small grocery stores, paan (betel leaf) and bidi (hand-rolled cigarette) vendors, street vendors, and tobacco specialists.

2.3 Questionnaire design and validation

A comprehensive self-designed, structured, and self-administered questionnaire comprising 53 closed-ended questions was developed in the English language to evaluate various tobacco-related activities in each outlet. The questionnaire was administered using the Epicollect5 platform, a free and easy-to-use mobile data-gathering platform and publicly available at https://five.epicollect.net. Key components from the COTPA Act, insights from Feighery et al. (22), and variables from the Global Youth Tobacco Survey (GYTS) and Global Adult Tobacco Survey (GATS) (23) were incorporated into the survey instrument. These variables encompassed aspects such as vendor types, advertisement types, branding practices, health warnings, compliance measures, and factors related to tobacco sales to minors, ensuring a comprehensive assessment of tobacco marketing practices and regulations (Supplementary File 1).

For reliability of the questionnaire, reliability analysis performed using SPSS, yielded a Cronbach Alpha coefficient of 0.797, demonstrating satisfactory internal consistency. The validity of the questionnaire was assessed through expert review to ensure clarity, understandability, and logical ordering of questions. Content validity was ensured by subjecting the questionnaire to scrutiny by experts involved in tobacco cessation activities, while face validity was assessed through feedback from these experts to ascertain the comprehensibility and relevance of the questionnaire content.

2.4 Data analysis

Descriptive frequency analysis was performed to analyze various vendor characteristics and compliance levels. Additionally, bivariate Chi-square analysis was conducted using IBM SPSS Statistics 25 to examine associations between government and private schools.

3 Results

3.1 Characteristics of tobacco vendors

The study investigated various vendor characteristics and levels compliance among 226 vendors located within 100 yards of schools. Out of these 226 vendors, 107 were identified as selling tobacco products. The average density/presence of tobacco vendors within 100 yards of the school premises are approximately 07 (6.68) (Figure 2).

3.2 Types of vendors

Among these vendors, pan vendors represented the majority (44.9%), followed by grocery/convenience stores (36.4%), tea stalls (8.4%), large stores/supermarkets (6.5%), and mobile vendors (3.7%) (Table 1). Notably, all 15 selected schools had nearby tobacco-selling vendors, except for one government school, indicating the widespread nature of the lapse.

3.3 Advertisement practices

In terms of advertisements in tobacco vendors, various types of advertisements were prevalent, including boards (15.9%), posters (22.4%), banners (8.4%), stickers (50.5%), dangles (33.6%), LCD/video screening/LED (12.1%), promotional gifts/offers (8.4%), and product displays (35.5%). Additionally, 48 (44.9%) vendors displayed brand pack shots or brand names of tobacco products, and 38 (34.6%) vendors used particular colors and layouts associated with specific tobacco products. Hoarding advertising of tobacco products larger than (60 cm × 45 cm) at the point of sale and more than two boards at the point of sale, was observed in 46 (43%) of vendors. Advertisement locations varied, with 26 (24.3%) placed in the exteriors and 50 (46.7%) placed inside the vendors. Advertisements were predominantly placed above 3 feet (28%) and below 3 feet (32.7%), while a smaller proportion was placed next to candy (12.1%).

Regarding health warning messages, compliance was suboptimal, with only 31 (29%) vendors displaying board/banner/poster health warnings as mandated by COTPA. Sixty one vendors, (57%) displayed tobacco brand names (Table 2).

3.4 Smoking in public places and sales to minors

Regarding smoking in public places, an alarming 62 (57.9%) of vendors allowed smoking within 100 yards of schools, posing a

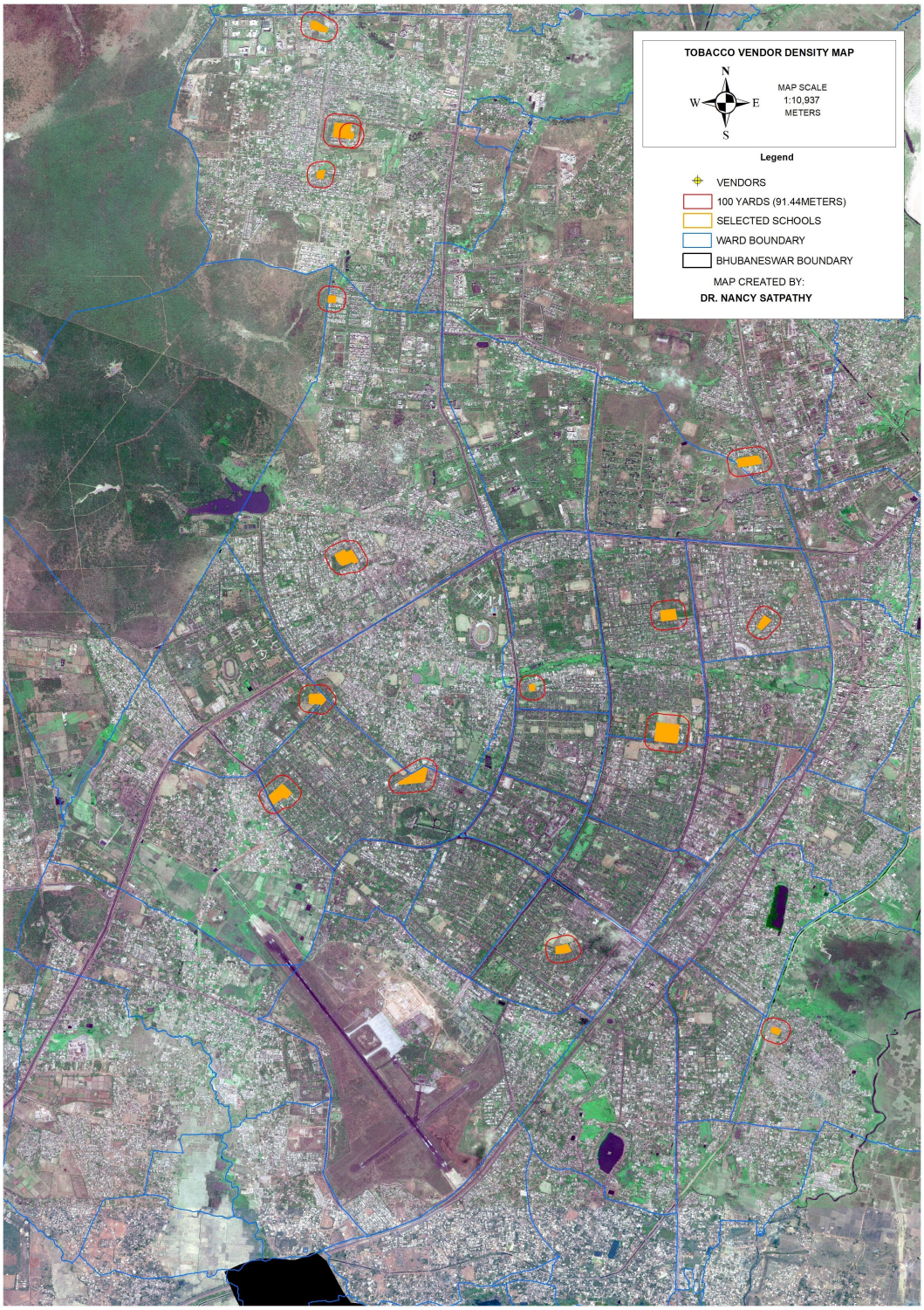

FIGURE 1
Mapping of all selected schools and a 100-yard zone around the schools.

significant public health challenge, particularly given their proximity to educational institutions. Signage near schools needed to be improved, with only 6 (5.6%) vendors displaying signage as required by law. The study also uncovered concerning trends related to tobacco sales to minors, with 52 (48.6%) vendors selling tobacco products to minors and 26 (24.3%) having tobacco products sold by minors (Supplementary File 2). These findings underscore the need for stringent enforcement measures to prevent youth access to tobacco products and protect minors from the harms of tobacco use (Table 3).

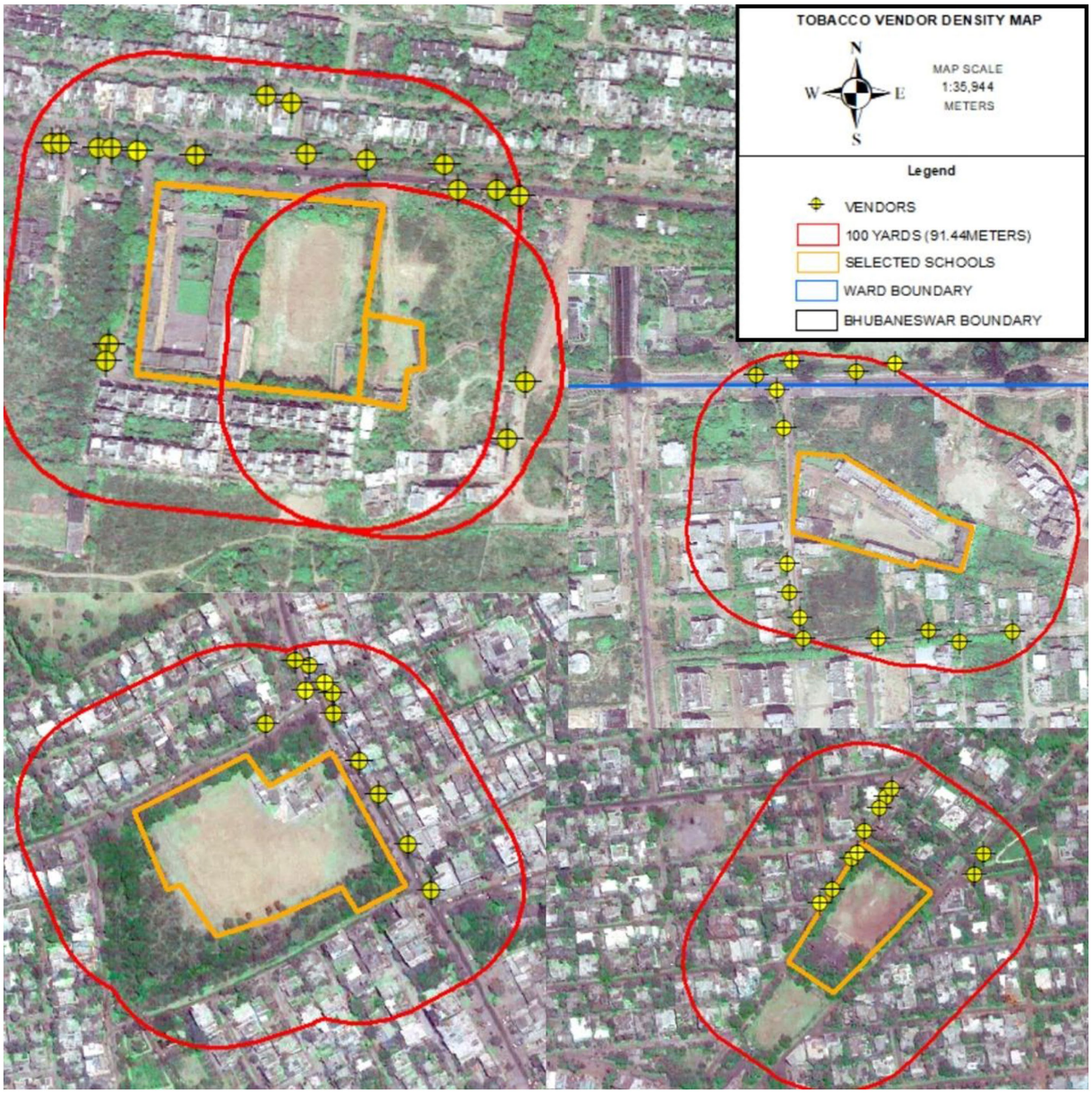

FIGURE 2
Geographic Information System (GIS) mapping of the 100-yard radius around five schools and the locations of tobacco vendors within this radius.

TABLE 1 **Vendor Characteristics around 100 yards of schools (*n* = 107).**

Variables	Govt schools (n)	(%)	Private schools (n)	(%)	Total (n)	(%)
Pan vendors	24	44.9	24	45.3	48	44.9
Tea stall	5	9.3	4	7.5	9	8.4
Grocery/convenience store	20	37	19	35.8	39	36.4
Large store/supermarket	4	7.4	3	5.7	7	6.5
Mobile vendor	1	1.9	3	5.7	4	3.7

3.5 Brand names displayed

The most commonly displayed tobacco brand names as direct adverstisements were Gold Flake (15%), Marlboro (23.4%), Classic (15.9%), Wills (3.7%), and Four Square (8.4%). Indirect advertisement practices also exhibited similar trends that included boards (15%), posters (36.4%), banners (29%), stickers (32.7%), and dangles (38.3%). Notably, tobacco brand names such as Vimal (3.7%), Bahar

TABLE 2 Compliance of tobacco vendors with COTPA section 5 of advertisement at point-of-sale around 100 yards of schools (n = 107).

Variables	Govt schools (n)	(%)	Private schools (n)	(%)	Total (n)	(%)
Advertisements in tobacco vendors	30	55.6	31	58.5	61	57
Type of advertisements—boards	10	18.5	7	13.2	17	15.9
Type of advertisements—posters	15	27.8	9	17	24	22.4
Type of advertisements—banners	6	11.1	3	5.7	9	8.4
Type of advertisements—stickers	26	48.1	29	54.7	55	50.5
Type of advertisements—dangles	20	37	16	30.2	36	33.6
Type of advertisements—LCD/video screening/LED	6	11.1	7	13.2	13	12.1
Type of advertisements—Promotional gifts/offers	6	11.1	3	5.7	9	8.4
Type of advertisements—product display	19	35.2	19	35.8	38	35.5
Advertisement board displays brand packshot or brand name of tobacco products	24	44.4	24	45.3	48	44.9
Whether the particular color and layout and/or presentation is used in an advertisement board that is associated to particular tobacco products	17	31.5	21	39.6	38	34.6
Presence of hoarding advertising tobacco products, larger than (60 cm × 45 cm) at point of sale and more than two boards at point of sale	24	44.4	22	41.5	46	43
Advertisement location-exterior	12	22.2	14	26.4	26	24.3
Advertisement location-interior	24	44.4	26	49.1	50	46.7
Advertisement placement- below 3 feet	19	35.2	16	30.2	35	32.7
Advertisement Placement- Next to Candy	8	14.8	5	9.4	13	12.1
Advertisement Placement-Above 3 feet	14	25.9	16	30.2	30	28
Presence of board/banner/poster displays a health warning	16	29.6	15	28.3	31	29
Whether health warning is on uppermost portion of a board	16	29.6	15	28.3	31	29
Whether health warning is written in any local Indian language (and/or English)	16	29.6	15	28.3	31	29
Name of the tobacco brand displayed?	28	51.9	29	54.7	61	57

(29.9%), Pan Bahar (23.4%), Ragnigadha (42.1%), Safal (46.7%), Meenajee (17.8%), Kamal Pasand (11.2%), Baba (9.3%), Signature (19.6%), and Tulsi (20.6%) were prominently displayed, indicating potential violations of regulations prohibiting tobacco advertising (Table 4).

3.6 Comparison between government and private schools

There was no significant difference between government and private schools with regard to various sections of the COTPA.

4 Discussion

4.1 Regulatory violations and tobacco vendor density

The findings highlight the alarming prevalence of tobacco vendors near schools, with widespread violations of tobacco control regulations. The high density of tobacco vendors within a 100-meter radius of schools raises serious concerns, as it increases the accessibility and visibility of tobacco products to students, a vulnerable population susceptible to tobacco use initiation (24). This proximity violates COTPA regulations, prohibiting the sale of tobacco products within a 100-yard radius of educational institutions (25). The study found an average tobacco vendor density of approximately seven within 100 yards of schools in Bhubaneswar City. Similar studies in Ranchi and Siliguri reported six and five vendors per square kilometer, respectively (26). This widespread presence of tobacco vendors near schools demonstrates the urgent need for stricter enforcement to protect students from early tobacco exposure.

4.2 International tobacco control measures and their relevance

Effective tobacco control measures, such as comprehensive smoke-free policies in public places, including educational institutions, have significantly reduced secondhand smoke exposure and tobacco use in countries like Australia, Canada, and the United Kingdom (27–29). Similarly, initiatives such as increased tobacco taxation, plain packaging regulations, and impactful anti-tobacco mass media campaigns have successfully reduced tobacco consumption, particularly among youth (30). While these measures have demonstrated success internationally, their implementation in India requires a context-specific approach considering socio-economic and cultural factors. Unlike high-income countries where strong

TABLE 3 Compliance of COTPA section 4 and section 6 regulations (n = 107).

Variables	Govt schools (n)	(%)	Private schools (n)	(%)	Total (n)	(%)
Presence of smoking 100 yards of educational institution	35	64.8	27	50.9	62	57.9
Signage near educational institutions (100 yards)	10	18.5	11	20.8	21	19.6
Display of signage as mandated in law 6(a) of COTPA	3	5.6	3	5.7	6	5.6
Tobacco products are sold by minors	12	22.2	14	26.4	26	24.3
Tobacco products are sold to minors	25	46.3	27	50.9	52	48.6

enforcement mechanisms and widespread public health awareness campaigns support compliance, India faces challenges such as weaker regulatory oversight, economic reliance on the tobacco industry, and varying levels of law enforcement efficiency across states (31). Adapting global best practices, such as strict enforcement of tobacco-free zones, graphic health warnings, and large-scale awareness campaigns, could significantly strengthen India's existing tobacco control framework.

4.3 Marketing strategies and tobacco advertising

The pervasive advertising and promotional activities near schools further exacerbate the problem. Vendors used various advertising methods, including boards, posters, banners, stickers, dangles, and product displays, many violating COTPA regulations (32, 33). The tobacco industry frequently employs aggressive marketing strategies such as the prominent display of brand names, distinctive color schemes, and specific layouts, which influence youth tobacco initiation. Studies have shown that increased exposure to tobacco advertising leads to higher initiation rates among adolescents, reinforcing the need for stricter enforcement of advertising bans (32, 33). Despite legal restrictions, the presence of such marketing techniques suggests a failure in enforcing tobacco control policies, necessitating stronger regulatory measures.

4.4 Health implications and youth exposure

The prevalence of smoking in public places near schools remains a significant public health concern. The study revealed that a majority of vendors, approximately 57.9%, allowed smoking within 100 yards of schools, exposing students and the general public to secondhand smoke, which is a well-established risk factor for respiratory diseases and cardiovascular conditions (34). Additionally, the absence of mandated health warning messages and signage near educational institutions represents a serious gap in compliance efforts (35, 36). The sale of tobacco products to minors is another critical concern, with nearly half of the vendors selling tobacco to minors, while a significant proportion had minors engaged in tobacco sales (37). These violations not only breach COTPA Section 6 but also contribute to early tobacco addiction and long-term health consequences (37). The presence of tobacco vendors near schools is also a violation of the Juvenile Justice Act, as it facilitates the sale of tobacco products to minors, a practice strictly prohibited under the law (38).

4.5 Policy interventions and enforcement strategies

Some states in India, such as Bihar, have demonstrated notable success in enforcing Tobacco-Free Educational Institution (TOFEI) guidelines, setting an example that Odisha could follow (39). Strategies involving regular compliance monitoring, strict penalties for violations, and collaboration with school authorities and community leaders have significantly improved implementation (40, 41). Training programs developed by the National Council of Educational Research and Training (NCERT) and directives from the Central Board of Secondary Education (CBSE) play a crucial role in educating teachers and school administrators about the importance of maintaining a tobacco-free environment (42, 43). Furthermore, intersectoral coordination between health, education, law enforcement, and civil society sectors, facilitated by bodies like the Tobacco Control Cell, is essential for ensuring the effective implementation of tobacco control laws (40).

To address these challenges, it is necessary to strengthen the enforcement of existing tobacco control laws, including COTPA and the Juvenile Justice Act, through regular monitoring and stringent penalties for violations (40). Implementing stricter regulations to completely eliminate tobacco advertising, promotion, and sponsorship, in line with the WHO Framework Convention on Tobacco Control (FCTC), can help reduce the influence of tobacco marketing on youth (44, 45). Additionally, enhancing community education and awareness campaigns, mainly targeting youth and their guardians, is crucial for preventing tobacco initiation and encouraging cessation (46).

4.6 Strengths of the study

This study has several key strengths that enhance its contribution to tobacco control research. It employs a rigorous methodology with a probability-proportional-to-size (PPS) sampling method, ensuring representative school selection in Bhubaneswar. The use of ArcGIS 10.8, Google Maps, and satellite imagery enhances the accuracy of vendor mapping within a 100-yard radius, providing quantitative evidence on vendor clustering and its potential impact on youth tobacco exposure. As one of the first studies to explore tobacco vendor density near schools in Odisha, it provides region-specific insights to inform state-level policy interventions. Additionally, it evaluates compliance with COTPA regulations (sections 4, 5, and 6), shedding light on gaps in enforcement, tobacco advertising violations, and sales to minors. Furthermore, the multi-dimensional analysis of tobacco marketing strategies, including direct and indirect advertising, highlights the tobacco industry's influence on youth tobacco initiation. These findings provide data-driven insights for strengthening tobacco-free school policies, zoning laws, and vendor

TABLE 4 Presence of brand names in tobacco vendor (direct and indirect advertisement).

Variables	Name of the tobacco brand	Govt schools (N)	(%)	Private schools (n)	(%)	Total (n)	(%)
Direct advertisement	Gold flake	7	13	9	17	16	15
	Marlboro	11	20.4	14	26.4	25	23.4
	Classic	8	14.8	9	17	17	15.9
	Total	4	7.4	3	5.7	7	6.5
	Wills	2	3.7	2	3.8	4	3.7
	Four square	3	5.6	6	11.3	9	8.4
Indirect advertisement	Vimal	2	3.7	2	3.8	4	3.7
	Bahar	16	29.6	16	30.2	32	29.9
	Pan bahar	10	18.5	15	28.3	25	23.4
	Ragnigadha	22	40.7	23	43.4	45	42.1
	Safal	24	44.4	26	49.1	50	46.7
	Meenajee	9	16.7	10	18.9	19	17.8
	Kamal pasand	3	5.6	9	17	12	11.2
	Baba	5	9.3	5	9.4	10	9.3
	Signature	11	20.4	10	18.9	21	19.6
	Tulsi	9	16.7	13	24.5	22	20.6

regulations, positioning this research as a valuable resource for policymakers, public health officials, and researchers working to enhance tobacco control efforts in India.

4.7 Limitations

The study has several limitations that warrant consideration. Firstly, the sample size was limited to 15 high schools in Bhubaneswar City, Odisha, which could constrain the applicability of the findings to other regions. Additionally, the cross-sectional design used in the study provides a static view and may not capture dynamic changes or trends over time. Reliance on observational assessments introduces the possibility of reporting bias, potentially impacting the accuracy of compliance levels or vendor practices reported. Furthermore, the study's focus on specific variables related to tobacco control near schools may overlook broader contextual factors and socioeconomic influences that could significantly influence tobacco use initiation among youth. These limitations highlight the need for future research with larger and more diverse samples, longitudinal designs, and comprehensive assessments of contextual factors to achieve in-depth understanding of tobacco control dynamics.

5 Conclusion

This study reveals a concerning landscape of widespread tobacco vendor density and regulatory non-compliance in the vicinity of educational institutions. The presence of numerous tobacco vendors within a 100-meter radius of schools, coupled with the pervasive display of tobacco advertisements and the sale of tobacco products to minors, highlights significant gaps in the implementation and enforcement of tobacco control regulations. These findings emphasize the urgent need for stronger policy interventions and consistent enforcement mechanisms to curb youth access to tobacco products. Additionally, community-driven initiatives and grassroots advocacy can play a pivotal role in strengthening local tobacco control efforts.

Efforts should be directed toward enhancing awareness campaigns, mainly targeting youth and their guardians. Involving various stakeholders, such as educational institutions, community leaders, and civil society organizations, and fostering intersectoral collaborations in tobacco control initiatives can foster a supportive environment for tobacco cessation and prevention. All stakeholder departments and enforcers should make concerted effort to protect the youth from exposure and use of tobacco products.

By addressing the multifaceted issues highlighted in this study, progress can be made in reducing the burden of tobacco-related morbidity and mortality, particularly among vulnerable populations like youth. Implementing a combination of strict regulatory enforcement, public health education, and continuous surveillance can create long-term, sustainable reductions in youth tobacco exposure and consumption.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

NS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. PJ: Conceptualization, Investigation, Project administration, Supervision, Validation, Visualization, Writing – review & editing. AY: Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – review & editing. VE: Conceptualization, Investigation, Methodology, Project administration, Supervision,

Validation, Visualization, Writing – review & editing. VM: Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. MA: Investigation, Validation, Visualization, Writing – review & editing. RK: Methodology, Writing – review & editing. YS: Supervision, Writing – review & editing. AP: Validation, Writing – review & editing.

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Conflict of interest

AY was employed by Vital Strategies, Inc.

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Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2025.1410114/full#supplementary-material

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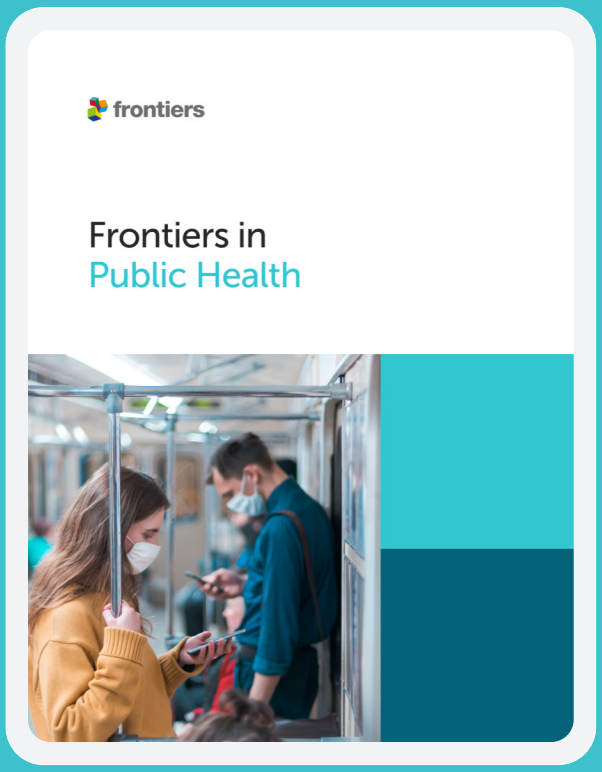

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