Tobacco advertising and oral health among never smokers: the mediating role of secondhand smoke exposure

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Objective: To determine whether the association between tobacco advertising (TA) exposure and poor self-rated oral health (SROH) is mediated through secondhand smoke (SHS) exposure in Brazilian adults who have never smoked. *Methods*: Secondary cross-sectional analysis of The Brazilian National Health Survey 2019 data. The daily, weekly, or monthly exposure to SHS at home or at work was set as the mediator. Mediation analysis within a counterfactual approach used adjusted binary logistic regressions for both poor SROH and SHS exposure, to estimate the natural direct effect (NDE), natural indirect effect (NIE) through SHS exposure, and marginal total effect (MTE) of TA exposure on poor SROH. To assess the robustness of the results, we calculated the E-value for the MTE. *Results*: The sample comprised 53,295 never smoker adults. The MTE of TA exposure on poor SROH was 1.09 (1.03, 1.16), with the indirect effect through SHS exposure responsible for only 16.6% of the total (NIE: 1.01 [1.01, 1.02] and NDE: 1.08 [1.02, 1.14]). An effect of 1.42 would be required for an unmeasured confounder to explain away the association between TA and SROH. *Conclusion*: More individuals exposed to TA have poor SROH than those unexposed, with secondhand smoke exposure explaining only a small portion of this effect. Upstream tobacco policies should consider oral health outcomes.

Keywords: oral health, self-assessment, tobacco industry, tobacco smoke pollution, mediation analysis

Introduction

Tobacco exposure is an important cause of (oral) noncommunicable chronic diseases (NCCD) (Ford *et al*., 2021); however, some aspects of such a complex exposure have not been explored in oral epidemiology, particularly those more conceptually distal to the conventional measures of amount or frequency of cigarette (or other tobacco products) consumption. One lesser-explored dimension is tobacco advertising (TA), employed by the industry to perpetuate the tobacco addiction pandemic (Oliveira da Silva *et al*., 2020). In general, TA associates cigarette consumption with pleasant environments, sports-related images, and notions of success, sophistication, and social interaction, ultimately influencing on consumer behavior (Freeman *et al*., 2022). In Brazil, all types of TA have been comprehensively prohibited since 2014, in line with the 2005 World Health Organization Framework Convention on Tobacco Control, allowing only the product to be displayed at the point of sale (i.e., markets and bars) (Malta *et al*., 2021). As restrictions on media-based advertising have become more stringent, tobacco companies have pursued promotional efforts at the point of sale to sustain the attractiveness of tobacco products (Bacelar Ferreira-Gomes *et al*., 2017).

Although previous research on TA has focused mainly on current smokers' health and behavior (Robertson *et al*., 2015), the exposure may also affect nonsmokers through secondhand smoke (SHS) exposure (Nian *et al*., 2023). SHS, also known as passive smoke, is produced from the burning of cigarettes and other tobacco products and smoke exhaled by a smoker (Arfaeinia *et al*., 2023).

SHS has been clearly linked to several adverse health consequences and, over the past three decades, the number of disability-adjusted life years (DALYs) attributed to this exposure more than doubled, especially affecting middle-income countries (Zhai *et al*., 2023). In Brazil, 27,000 deaths (1.9% of the total) and 771,000 DALYs (1.1% of the total) were attributed to SHS exposure in 2019 (Malta *et al*., 2021). On the spectrum of oral NCCD, SHS has been linked to dental caries (Saho *et al*., 2020), periodontal diseases (Akinkugbe *et al*., 2016), tooth loss (Inoue *et al*., 2021), and oral cancer (Mariano *et al*., 2022), and might mediate the relationship between TA and oral health among never smokers. Importantly, while the impact of TA on current smoking habits (that ultimately influence the occurrence of oral NCCD) is presumed, comprehending how TA, SHS and oral health are associated can guide the implementation of broader preventive interventions that also encompass nonsmokers.

This study aimed to explore the mediating role of SHS exposure on the association between TA and poor oral health among never smokers. We hypothesized that those exposed to TA would be more likely to have poor oral health, and that such an association would be partially explained due to higher exposure to SHS.

Method

This cross-sectional study used data from the 2019 Brazilian National Health Survey (PNS 2019), a nationally representative household survey conducted by the Brazilian Institute of Geography and Statistics in collaboration with the Brazilian Ministry of Health. The fieldwork was

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performed between August 2019 and March 2020, with trained examiners using mobile devices pre-programmed for household and individual interviews. Before participating all participants received a comprehensive explanation of the study's procedures and signed a statement of informed consent. The Brazilian National Ethics Research Committee from the Brazilian Ministry of Health independently reviewed and approved the study protocol (n. 3.529.376), and all procedures were in accordance with the Declaration of Helsinki.

The population consisted of residents living in permanent private households in Brazil. Sampling took place in three stages. First, the census tracts were selected; second, the households and finally one resident aged 15 years or more was drawn from each selected household. More information can be found elsewhere (Stopa *et al.*, 2020). This study examined data from adults aged 18 years or older (N=88,531), excluding former and current smokers (N=35,236), leading to a total sample of 53,295 adults. This exclusion is a common practice when investigating the effects of SHS on health, as the substantial impact of active smoking is believed to potentially overshadow more subtle health effects associated with SHS (Carreras *et al.*, 2019).

The study outcome, Self-rated oral health (SROH) was assessed with the global question "In general, how do you rate your oral health (teeth and gums)?". Participants were categorized as having "poor SROH" if they rated their oral health as fair, bad, or very bad or having "good SROH" if they rated their oral health as very good or good.

The exposure to TA was determined by asking "during the past month, have you seen any advertisement or announcement about cigarettes at points of sale?" (yes/no). Information on SHS was collected using the questions "how often does someone smoke inside your home?" with answers ranging from "never" to "daily"; and "during the past month, did someone smoke in the same enclosed place where you work?" (yes/no). Thereafter, we defined individuals as being exposed to SHS if they reported daily, weekly, or monthly exposure at home (Tripathy, 2020) or if they reported exposure at work.

Covariates included sex; skin color (white or nonwhite); age (dichotomized in < 50 or ≥ 50 years); education (incomplete elementary school, incomplete secondary school, and complete secondary school); per capita household income (≤ 1 or > 1 Brazilian monthly minimum wage [BMMW]. 1 BMMW ≈ US$ 202 during study period); and household wealth, a measure produced pooling information on the ownership of durable goods (i.e., car, washing machine, microwave) using principal component analysis (firstly categorized in terciles and after dichotomized in lowest or medium/highest terciles).

All analyses were performed using Stata software, version 14.0 (Stata Corporation; College Station, TX). Descriptive analysis adopted sample weights for primary sampling units, households, and the selected resident, in accordance with the complex survey sampling. Estimates were presented as overall relative frequencies along with their corresponding 95% confidence intervals (CI). Afterwards, we employed a mediation analysis within a counterfactual approach (using "paramed" command)

to test whether SHS exposure mediated the association between TA and SROH. This approach relies on the assumptions of consistency, positivity, exchangeability (exposure-outcome, mediator-outcome, and exposure-mediator paths), faithfulness, and that none of the mediator-outcome confounders are affected by the exposure. Binary logistic regressions were fitted for both outcome and mediator models, enabling the calculation of odds ratios (OR) and respective 95% CI. We estimated the natural direct effect (NDE) – the effect of TA on SROH that is not mediated by SHS; the natural indirect effect (NIE) – the effect of TA on SROH mediated through SHS; and the marginal total effect (MTE). The proportion mediated was then calculated as: (NDE) x (NIE − 1)/(NDE x NIE − 1) (Bartick *et al.*, 2022). CIs were estimated using the bootstrap method. Models were adjusted for the covariates described earlier.

To determine the robustness of the results, we calculated E-values for the OR. The E-value represents the minimum strength of association that an unmeasured confounder would need to have with both the exposure and outcome to eliminate the observed effect, adjusted for covariates. A large E-value would imply that considerable unmeasured confounding would be needed to nullify the effect estimate.

This manuscript was prepared according to the reporting recommendations found in the AGReMa (A Guideline for Reporting Mediation Analysis) checklist (Lee *et al.*, 2021).

Results

Most participants rated their oral health as good and were unexposed to TA and SHS. Socioeconomic gradients were observed in relation to the occurrence of poor SROH. Although never smokers exposed to SHS presented higher occurrence of poor SROH, those exposed to TA had a slightly lower prevalence of the outcome (Table 1).

Figure 1 illustrates the interplay of the analyzed factors. Both TA (adjusted OR = 1.08; 95% CI: 1.02; 1.14) and SHS (adjusted OR = 1.23; 95% CI: 1.16; 1.31) exposures were positively associated with poor SROH. In mediation analysis, the findings suggest that the total effect of TA exposure on poor SROH was 9% (ranging from 3% to 16%). When decomposing direct and indirect effects, the former accounted for 8% (ranging from 2% to 14%) and the latter was 1% (ranging from 1% to 2%). This indicates that a total of 16.6% of TA effects were mediated through SHS exposure. The sensitivity analysis for unmeasured confounding suggested an E-value of 1.42, meaning that a 1.4-fold effect would be required for an unmeasured confounder to explain away this association (Table 2).

Discussion

While the impact of TA on current smokers' behaviors is expected and already documented (Robertson *et al.*, 2015), its influence on the (oral) health of nonsmokers is less clear. In this context, this study contributes to the literature in two important ways. First, by analyzing nationally representative data from Brazil, our findings suggest that TA associates with poor SROH among never

Table 1. Characteristics of 53,295 never smokers enrolled in the 2019 Brazilian National Health Survey.

Variables	Weighted % (95% CI[a])	Weighted poor SROH *% (95% CI)
Total		27.1 (26.4; 27.8)
Sex		
Male	44.1 (43.4; 44.9)	27.7 (26.6; 28.8)
Women	55.9 (55.1; 56.6)	26.7 (25.8; 27.6)
Skin color		
White	44.1 (43.2; 45.0)	22.2 (21.1; 23.3)
Non-white	55.9 (55.0; 56.8)	31.0 (30.1; 32.0)
Age		
< 50 years	69.0 (68.2; 69.7)	24.9 (24.0; 25.7)
≥ 50 years	31.0 (30.3; 31.8)	32.2 (31.0; 33.4)
Per capita household income		
> 1 BMMW†	50.4 (49.4; 51.4)	19.9 (19.0; 20.8)
≤ 1 BMMW	49.6 (48.6; 50.6)	34.5 (33.5; 35.5)
Education		
Complete secondary school	58.1 (57.2; 58.9)	20.6 (19.7; 21.4)
Incomplete secondary school	14.0 (13.4; 14.5)	32.7 (30.8; 34.8)
Incomplete elementary school	28.0 (27.2; 28.7)	38.0 (36.7; 39.3)
Household wealth		
Highest and medium terciles	75.4 (74.8; 76.1)	23.7 (22.9; 24.6)
Lowest tercile	24.6 (23.9; 25.2)	37.6 (36.4; 38.7)
Secondhand smoke		
Unexposed	89.0 (88.4; 89.4)	26.6 (25.9; 27.4)
Exposed	11.0 (10.6; 11.6)	31.4 (29.2; 33.7)
Tobacco advertisement		
Unexposed	83.7 (82.8; 84.7)	27.3 (26.6; 28.1)
Exposed	16.3 (15.3; 17.2)	26.1 (24.3; 27.9)

*SROH, self-rated oral health;
†BMMW, Brazilian minimum monthly wage;
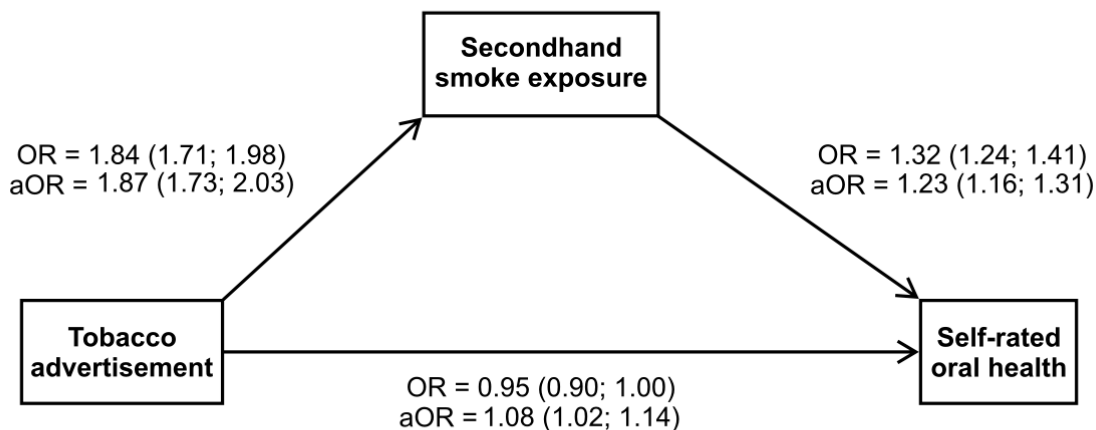
Figure 1. Triangle using separate regression models for the association between tobacco advertisement, secondhand smoke exposure, and self-rated oral health.

Table 2. Mediation analysis of tobacco advertisement exposure on self-rated oral health, mediated by secondhand smoke exposure.

	Odds Ratio (95% CI)
Natural direct effect	1.08 (1.02; 1.14)
Natural indirect effect	1.01 (1.01; 1.02)
Total effect	1.09 (1.03; 1.16)
E-value	1.42
Proportion mediated	16.6%

smokers. We must highlight, however, that the point estimate for such an effect is small (1.09). Secondly, it shows that a little proportion of such an effect is mediated by SHS. To the best of our knowledge, this is the first study to identify these associations in relation to oral health. However, caution should be exercised when extrapolating the findings to other populations, as tobacco control policies may vary across countries.

This study had certain limitations. No temporal inference can be established as only cross-sectional data were analyzed. Therefore, although a robust approach for causal mediation analysis was employed, the findings are merely suggestive. Secondly, residual and unmeasured confounding may affect the estimates. To address this concern, a sensitivity analysis considering the E-value was performed, indicating that an effect of 1.42 would be necessary to nullify the observed relationship. Thirdly, the exposure to SHS was collected only at home and at the workplace, but there is the possibility that some individuals not exposed to SHS at home or the workplace were exposed in other public places, such as restaurants and bars. Lastly, data at municipality level were not available, which would be important to manage TA as a contextual variable and to assess other contextual determinants that possibly influence the pathway described.

Previous studies have demonstrated that individuals exposed to TA are more likely to be exposed to SHS (Nian *et al.*, 2023), which has been associated with worse oral health (Akinkugbe *et al.*, 2016; Saho *et al.*, 2020; Inoue *et al.*, 2021). Interestingly, we found that this pathway explains only a small portion of the total effect of TA on SROH, and two explanations can be proposed in this regard. The first relates to residual confounding due to the self-reported SHS exposure. A previous study indicated that self-reported surveys of SHS exposure in the home and workplace yield lower estimates than measurements of serum cotinine, an objective biomarker of nicotine exposure (Max *et al.*, 2009). Additionally, social norms may lead to underreporting of SHS exposure. The second explanation pertains to a set of other mediators that jointly contribute more than SHS alone. It is plausible that those exposed to TA are also exposed to other adverse health habits, such as greater consumption of sugar-sweetened drinks and alcohol. However, to the best of our knowledge, there is no study associating TA with deleterious health habits other than current smoking or SHS. Therefore, we did not include these and other variables in the model. Moreover, it is possible that the context in which individuals exposed to TA are situated is subject to less regulation and legislation of markets and health services, contributing to, for instance, low quality of the products consumed and lower health access, ultimately leading to poorer oral health.

Considering that SHS explains only a small proportion of the effect of TA on SROH, the main practical implication of our findings underscores the necessity of integrated upstream public health policies. These policies should include stronger and stricter regulations on the advertising and promotion of tobacco, alongside other integrated efforts aimed at addressing shared common risk factors (i.e., SHS exposure). Given the challenges of interventions to reduce SHS at home, it is of public health interest to evaluate the role of precursors to such a factor. Ultimately, these efforts may have a positive impact on both oral and general health outcomes for both current and nonsmokers.

In conclusion, more individuals exposed to TA had poor SROH than those unexposed, with SHS exposure explaining only a small portion of this effect. Upstream tobacco policies should consider oral health outcomes.

Acknowledgments

Data Availability Statement

The data that support the findings of this study are openly available at: https://www.ibge.gov.br/estatisticas/sociais/saude/9160-pesquisa-nacional-de-saude.html?=&t=downloads

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