

Prevalence of Underreported Nicotine Exposure Among US Nonsmoking Adults: A Comparison of Self-Reported Exposure and Serum Cotinine Levels From NHANES 2013–2020

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Abstract

Introduction: Secondhand smoke (SHS) poses a significant health risk. However, individuals who do not smoke may be unaware of their exposure, thereby failing to take protective actions promptly.

Aims and Methods: We assessed the prevalence of underreported nicotine exposure in a nationally representative sample of US nonsmoking adults using data from the US National Health and Examination Survey. Individuals with underreported nicotine exposure were defined as those who reported no exposure to all tobacco products (traditional tobacco, nicotine replacements, and e-cigarettes) or SHS, yet had detectable levels of serum cotinine (>0.015 ng/mL). We fitted logistic regression models to determine sociodemographic and chronic condition factors associated with underreported nicotine exposure.

Results: Our analysis included 13 503 adults aged 18 years and older. Between 2013 and 2020, the prevalence of self-reported SHS exposure, serum cotinine-assessed nicotine exposure, and underreported nicotine exposure among US nonsmokers were 22.0%, 51.2%, and 34.6%, respectively. Remarkably, 67.6% with detectable serum cotinine reported no SHS exposure. Males, non-Hispanic blacks, individuals of other races (including Asian Americans, Native Americans, and Pacific Islanders), and those without cardiovascular diseases were more likely to underreport nicotine exposure than their counterparts. The median serum cotinine value was higher in respondents who reported SHS exposure (0.107 ng/mL) than in those who reported no exposure (0.035 ng/mL). We estimate that approximately 56 million US residents had underreported nicotine exposure.

Conclusions: Over a third of US nonsmokers underreport their nicotine exposure, underlining the urgent need for comprehensive public awareness campaigns and interventions. Further research into sociodemographic determinants influencing this underreporting is needed.

Implications: Understanding the extent of underreported nicotine exposure is crucial for developing effective public health strategies and interventions. It is imperative to bolster public consciousness about the risks associated with SHS. Additionally, surveillance tools should also incorporate measures of exposure to outdoor SHS and e-cigarette vapor to enhance the quality of data monitoring. Findings from this study can guide tobacco control initiatives and inform smoke-free air legislation.

Background

Secondhand smoke (SHS), also known as passive smoke or environmental tobacco smoke, can cause premature death and various diseases among individuals who do not smoke.^{1–3} SHS exposure has immediate adverse effects on the cardiovascular system^{2,3} and is linked with chronic conditions such as coronary heart disease,^{4–6} respiratory disease,⁷ and cancers.^{8–11} Early exposure to SHS during prenatal and childhood stages can impair lung growth and increase the risk of developing chronic obstructive pulmonary diseases and lung cancer in adulthood.^{12,13} There is no safe level of exposure

to SHS.² However, many nonsmokers remain unaware of their exposure to tobacco smoke, leaving them at unnoticed elevated health risks.¹⁴ Moreover, relying on self-reported measurements could result in underestimations of the prevalence of SHS exposure.^{14,15}

Nicotine is a highly tobacco-specific component of cigarette smoke.² Cotinine, the primary metabolite of nicotine, is considered the most reliable biomarker for assessing SHS exposure in nonsmokers.^{16,17} Cotinine has a half-life averaging between 16 and 18 hours, longer than the 2-hour half-life of nicotine.¹⁷ Underreported nicotine exposure in

nonsmokers occurs when individuals report no recent tobacco use or SHS exposure yet present detectable levels of cotinine in their serum, urine, or saliva.^{14,15} A previous study using data from the National Health and Nutrition Examination Survey (NHANES) 1988–2004, a US-based study on the US nationally representative sample, found that 70% of nonsmoking workers with nicotine exposure (serum cotinine levels between 0.015 and 15 ng/mL) considered themselves as unexposed.¹⁸ In NHANES 2015–2016, 53.1% of US nonsmokers had serum cotinine levels between 0.015 and 10 ng/mL,¹⁹ but only 18.8% reported recent SHS exposure.²⁰ Despite the continued discrepancies in a significant proportion of the US nonsmoking population, the underreporting of SHS has not been thoroughly examined.

This study seeks to bridge this knowledge gap by estimating the prevalence of underreported nicotine exposure using a nationally representative sample of US nonsmoking adults. We also identified the sociodemographic characteristics and medical history factors associated with the underreporting. Understanding the patterns of underreported nicotine exposure is critical for shaping targeted tobacco control interventions, protecting nonsmokers, and reducing health and economic burdens attributed to smoking.

Method

Study population and design

This cross-sectional study used secondary data from nationally representative samples from the NHANES 2013–2020. NHANES is a multistage, stratified, clustered survey program that continuously collects data to monitor the health and nutritional status of the US population conducted by the National Center for Health Statistics.^{20,21} Respondents in NHANES completed in-person household interviews and physical examinations in a Mobile Examination Center.²² Data on self-reported indoor SHS exposure were available in four cycles (2013–2020), and data on serum cotinine were available in all cycles. Because of the COVID-19 pandemic, data collection for the 2019–2020 cycle was interrupted, and the partial data were combined with the previous cycle (2017–2018).²¹ We used three cycles from NHANES 2013–2020 to generate a nationally representative estimate.

We initially extracted data of 35 706 respondents from NHANES and excluded 21 458 respondents who were under 18 years old, and reported any tobacco use (ie, cigarettes, cigars, hookah/waterpipes, e-cigarettes, chewing tobacco, snuff, and nicotine replacement therapy products) in the past five days, and self-identified as current smokers (defined as individuals who had smoked ≥ 100 cigarettes in their lifetime and were currently smoking). We also excluded 7955 respondents with missing information on tobacco use, self-reported SHS exposure, and serum cotinine data. A total of 13 503 adults (weighted population = 163 815 204) were included in the final analysis. We additionally collected data on sociodemographic characteristics, smoking history, and chronic conditions. The University of Florida institutional review board ruled the analysis of this public dataset exempt. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology Statement guidelines.²³

Self-reported SHS exposure, serum cotinine-assessed nicotine exposure, and underreported nicotine exposure

Indoor SHS exposure was self-reported during the in-person interview. Respondents were asked if they were exposed to someone else's smoke from cigarettes or other tobacco products in an indoor area at home, workplace, restaurant, bar, car, other's home, and other indoor areas over the past seven days (see [Supplementary Table](#) for NHANES questions).²⁰ Data on exposure to secondhand e-cigarette vapor were only available in the 2017–2020 cycle. To assess SHS exposure at home, respondents were first asked how many people living in their home smoke tobacco indoors. If they reported that at least one household member smoked inside the house, they were further asked, "During the past seven days, on how many days did anyone who lives here smoke tobacco inside this home?" If the answer was between 1 and 7, they were considered to have SHS exposure. For other locations, the respondents were first asked a filter question for other locations to determine whether they were present in this location during the past seven days. If the answer was "Yes," they were asked the follow-up question: "While in this place, did someone else smoke cigarettes or other tobacco products indoors?" If the answer was yes, they were considered to have SHS exposure.

Serum cotinine was used to measure nicotine exposure. With an average half-life of 16 hours, serum cotinine reflects recent exposure to nicotine.¹⁶ The optimal cut-point to distinguish smokers from nonsmokers using cotinine is influenced by the prevalence and intensity of SHS exposure as well as race and metabolic difference, and self-reported nonsmokers can have serum cotinine values higher than smokers.^{24,25} Given the very heavy SHS exposure possibility, respondents with high levels of serum cotinine were not excluded. Instead, we segmented all included respondents with serum cotinine levels above the lower limit of detection (LLOD), which is 0.015 ng/mL, into four categories for further examination of underreporting based on cotinine levels: low (LLOD to <1 ng/mL), moderate (1 to <3 ng/mL), high (3 to <12 ng/mL), and very high (≥ 12 ng/mL).^{17,26} Detailed descriptions of the laboratory methods used are documented elsewhere.²⁶ We defined respondents with underreported nicotine exposure as those who reported no current use of any tobacco products or exposure to SHS exposure yet had detectable serum cotinine levels (≥ 0.015 ng/mL).

Sociodemographic characteristics, smoking history, and chronic conditions

We selected sociodemographic and health-related factors that could affect the link between SHS and smoking related as covariates in the analysis. Sociodemographic characteristics included age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and Other [including Asian, American Indian, Alaskan Native, Native Hawaiian or Pacific Islander, and multiracial]), education level, household income level, and marital status. Individuals were classified as former smokers if they had consumed at least 100 cigarettes in their lifetime but were not currently smoking. Chronic conditions included cardiovascular diseases (heart failure, coronary heart disease, heart attack, and stroke) and chronic respiratory diseases (asthma, emphysema, chronic bronchitis, and

chronic obstructive pulmonary disease) diagnosed by a health professional.²⁷

Statistical analyses

First, we calculated the prevalence and 95% confidence interval (CI) of self-reported SHS exposure, cotinine-assessed nicotine exposure, and underreported nicotine exposure. Then, we conducted multivariable logistic regression models to identify associated factors with self-reported SHS exposure, cotinine-assessed nicotine exposure, and underreported nicotine exposure. Third, we estimated the prevalence and weighted population of underreported nicotine exposure by serum cotinine level. We also plotted the distributions of serum cotinine concentrations stratified by self-reported SHS exposure status and smoking history.

All analyses followed the NHANES analytic guidelines and incorporated the sample weights to produce nationally representative estimates.²¹ Analyses were conducted using Stata 17.0 (College Station, TX: StataCorp LLC). Statistical significance was set at $p < .05$.

Results

Table 1 shows the characteristics of 13 503 respondents. All respondents self-identified as noncurrent smokers and had complete data on indoor SHS exposure and serum cotinine.

Prevalence of self-reported SHS exposure, cotinine-assessed nicotine exposure, and underreported nicotine exposure

The prevalence of self-reported SHS exposure, cotinine-assessed nicotine exposure, and underreported nicotine exposure was 22.0% (95% CI, 20.4 to 23.6), 51.2% (95% CI, 49.0 to 53.3), and 34.6% (95% CI, 32.9 to 36.3), respectively. Younger adults had a higher prevalence of self-reported SHS exposure and cotinine-assessed nicotine exposure compared with their older counterparts (p for trends = .03). However, age differences were not significant concerning underreported nicotine exposure. Males had a higher prevalence of self-reported SHS exposure (25.6%) and cotinine-assessed nicotine exposure (54.0%) than females (19.0% and 48.9%, respectively). Interestingly, both genders showed an identical prevalence of underreported nicotine exposure at 34.6%. Non-Hispanic blacks had higher prevalence across all categories: self-reported SHS exposure (31.5%), cotinine-assessed nicotine exposure (74.6%), and underreported nicotine exposure (45.5%) than their Non-Hispanic white counterparts (19.7%, 46.3%, and 31.9%, respectively). Hispanics indicated a higher prevalence of self-reported SHS exposure at 25.8%. Nonsmokers from other racial backgrounds had markedly higher prevalence of cotinine-assessed exposure (65.1%) and underreported exposure (48.3%) compared with Non-Hispanic whites, despite the similar self-reported prevalence (21.2%). Individuals with education levels below high school or equivalent to high school had higher prevalence rates in all three categories. Specifically, those with less than a high school education reported 26.0% (self-reported SHS exposure), 61.5% (cotinine-assessed nicotine exposure), and 40.1% (underreported nicotine exposure). For those with a high school education, the rates were 27.9%, 61.1%, and 37.6%, respectively. In comparison, individuals with education beyond high school had lower rates: 19.6%, 46.7%, and 32.8%, respectively. Lower household income

Table 1. Characteristics of US Nonsmoking Adult, NHANES 2013–2020¹

	No. of participants (Weighted%)
Overall	13 503 (100.0%)
Age	
18–39	4383 (34.3%)
40–65	5707 (43.9%)
>65	3413 (21.9%)
Sex	
Male	6043 (45.2%)
Female	7460 (54.8%)
Race	
Non-Hispanic white	4879 (64.7%)
Non-Hispanic black	2721 (9.6%)
Hispanic	3736 (16.7%)
Other	2167 (9.0%)
Education level	
Less than high school	2415 (10.7%)
High school	2646 (20.3%)
Greater than high school	8442 (69.0%)
Household income level	
<130% FPL ²	3256 (15.6%)
130%–350% FPL	6030 (39.8%)
≥350% FPL	4217 (44.6%)
Marital status	
Married/living with partner	7982 (64.3%)
Widowed/divorced/separated	2743 (17.1%)
Never married	2099 (15.6%)
Smoking history	
Never smoker	9911 (71.9%)
Former smoker	3592 (28.1%)
History of cardiovascular disease	
No	12 362 (93.1%)
Yes	1141 (6.9%)
History of chronic respiratory disease	
No	11 247 (83.3%)
Yes	2256 (16.7%)
Survey cycle	
2013–2014	3864 (27.0%)
2015–2016	3705 (26.7%)
2017–2020	5934 (46.3%)

¹Smoking status was based on self-reported information.

²Federal Poverty Level.

corresponded with a higher prevalence in all three categories (all p -values < .05). Respondents who were widowed, divorced, separated, or never married had a higher prevalence of all three outcomes than their counterparts who were married or living with a partner. Former smokers (56.1%) were more likely to have cotinine-assessed nicotine exposure than never smokers (49.2%). However, the likelihood to underreport nicotine exposure was not significantly different between the two groups. There were no significant differences in all prevalence based on the history of cardiovascular and chronic respiratory diseases. The self-reported SHS exposure prevalence in the 2017–2020 NHANES cycle (26.3%) was higher

Table 2. Prevalence of Self-Reported SHS Exposure, Cotinine-Assessed Nicotine Exposure, and Underreported Nicotine Exposure by Sociodemographic Characteristics and Chronic Conditions, NHANES 2013–2020¹

	Prevalence, % (95% CI)		
	Self-reported SHS exposure	Cotinine-assessed nicotine exposure	Underreported nicotine exposure
Overall	22.0 (20.4–23.6)	51.2 (49.0–53.3)	34.6 (32.9–36.3)
Age			
18–39	30.3 (28.1–32.6)	59.7 (56.8–62.5)	35.7 (33.1–38.2)
40–65	20.3 (18.1–22.5)	49.1 (46.5–51.6)	34.5 (32.4–36.6)
>65	12.2 (10.6–13.8)	42.1 (39.1–45.1)	33.0 (30.3–35.7)
<i>P for trend</i>	.003	<.001	.183
Sex			
Male	25.6 (23.2–28.1)	54.0 (51.8–56.2)	34.6 (32.6–36.5)
Female	19.0 (17.6–20.4)	48.9 (46.4–51.3)	34.6 (32.6–36.6)
Race			
Non-Hispanic white	19.7 (17.7–21.8)	46.3 (43.0–49.6)	31.9 (29.8–34.0)
Non-Hispanic black	31.4 (29.5–33.4)	74.6 (67.4–81.7)	45.5 (40.3–50.7)
Hispanic	25.8 (23.6–28.0)	49.1 (39.3–58.9)	31.2 (25.5–36.8)
Other	21.2 (18.7–23.6)	65.1 (59.0–71.2)	48.3 (43.4–53.3)
Education level			
Less than high school	26.0 (23.4–28.7)	61.5 (57.4–65.6)	40.1 (36.8–43.3)
High school	27.9 (24.7–31.1)	61.1 (57.6–64.6)	37.6 (34.4–40.8)
Greater than high school	19.6 (18.0–21.2)	46.7 (44.5–48.8)	32.8 (31.1–34.6)
Household income level			
<130% FPL ²	29.2 (27.0–31.4)	67.5 (63.8–71.2)	42.8 (39.9–45.8)
130%–350% FPL	24.0 (21.8–26.1)	54.7 (52.2–57.2)	35.7 (33.5–37.8)
≥350% FPL	17.7 (15.5–19.9)	42.3 (39.7–45.0)	30.7 (28.4–33.1)
Marital status			
Married/living with partner	18.6 (17.1–20.2)	46.0 (43.7–48.3)	32.7 (30.8–34.6)
Widowed/divorced/separated	21.1 (18.5–23.6)	55.4 (51.8–59.0)	39.1 (36.1–42.1)
Never married	34.0 (31.0–37.0)	65.6 (62.5–68.8)	37.6 (34.3–40.9)
Smoking history			
Never smoker	20.9 (19.2–22.7)	49.2 (46.9–51.6)	33.9 (32.1–35.7)
Former smoker	24.7 (22.4–26.9)	56.1 (53.0–59.2)	36.3 (33.5–39.0)
History of cardiovascular disease			
No	22.2 (20.6–23.8)	51.3 (49.0–53.5)	34.6 (32.9–36.3)
Yes	19.1 (15.3–22.9)	49.6 (44.4–54.8)	34.6 (30.4–38.9)
History of chronic respiratory disease			
No	21.7 (19.9–23.5)	50.5 (48.2–52.8)	34.3 (32.6–36.0)
Yes	23.5 (20.4–26.5)	54.5 (51.3–57.7)	35.8 (33.1–38.6)
Survey cycle			
2013–2014	20.1 (17.7–22.5)	52.3 (46.9–57.8)	37.3 (33.9–40.7)
2015–2016	16.5 (14.1–18.8)	51.0 (47.2–54.8)	38.4 (35.3–41.5)
2017–2020	26.3 (23.2–29.4)	50.6 (47.5–53.7)	30.8 (27.9–33.6)

¹All estimates were weighted to be nationally representative.²Federal Poverty Level.

than the other two cycles (20.1%, 16.5%), and the prevalence of underreported nicotine exposure was lower in the same cycle (30.8% vs. 37.3%, 38.4%) (Tables 2 and 3).

Characteristics associated with underreported nicotine exposure

After adjusting for sociodemographic characteristics and chronic conditions, male (reference; female OR 0.96 [95% CI, 0.93 to 0.99]), non-Hispanic black (OR 1.56 [95% CI,

1.33 to 1.82]), individuals of other races (OR 1.95 [95% CI 1.76 to 2.16]), and those without cardiovascular disease (reference; with history: OR 0.97 [95% CI 0.95 to 0.99]) were more likely to underreport nicotine exposure.

The characteristics associated with self-reported SHS exposure and cotinine measures were similar. Those who were younger, male, non-Hispanic black, of other races, with lower household income, not married or living with a partner, and having a smoking history were more likely to have both

Table 3. Correlates of Self-Reported SHS Exposure, Cotinine-Assessed Nicotine, and Underreported Nicotine Exposure, NHANES 2013–2020

	Self-reported SHS exposure	Odd ratio (95% CI)	
		Cotinine-assessed nicotine exposure	Underreported nicotine exposure
Age, in years			
18–39	[Reference]	[Reference]	[Reference]
40–65	0.64 (0.41–0.99)	0.71 (0.62–0.80)	0.96 (0.67–1.38)
>65	0.29 (0.11–0.78)	0.42 (0.37–0.49)	0.82 (0.50–1.37)
Sex			
Male	[Reference]	[Reference]	[Reference]
Female	0.67 (0.64–0.71)	0.77 (0.72–0.82)	0.96 (0.93–0.99)
Race/ethnicity			
Non-Hispanic white	[Reference]	[Reference]	[Reference]
Non-Hispanic black	1.51 (1.21–1.89)	2.63 (1.77–3.89)	1.56 (1.33–1.82)
Hispanic	1.03 (0.86–1.24)	0.70 (0.45–1.07)	0.78 (0.57–1.08)
Other	1.00 (0.71–1.39)	2.06 (1.87–2.26)	1.95 (1.76–2.16)
Education level			
Less than high school	[Reference]	[Reference]	[Reference]
High school	1.11 (1.03–1.19)	0.98 (0.68–1.41)	0.91 (0.66–1.25)
Greater than high school	0.71 (0.36–1.41)	0.56 (0.54–0.59)	0.77 (0.47–1.27)
Household income level			
<130% of FPL ¹	1.39 (0.67–2.88)	2.12 (1.42–3.16)	1.52 (0.65–3.52)
130%–350% of FPL	1.29 (0.59–2.84)	1.42 (1.30–1.55)	1.17 (0.64–2.15)
≥350% of FPL	[Reference]	[Reference]	[Reference]
Marital status			
Married/living with a partner	[Reference]	[Reference]	[Reference]
Widowed/divorced/separated	1.42 (0.72–2.80)	1.50 (1.31–1.71)	1.26 (0.89–1.77)
Never married	1.63 (1.22–2.17)	1.60 (1.30–1.96)	1.08 (0.71–1.65)
Smoking history			
Never smoker	[Reference]	[Reference]	[Reference]
Former smoker	1.54 (1.31–1.80)	1.58 (1.11–2.24)	1.16 (0.84–1.62)
Cardiovascular diseases			
No	[Reference]	[Reference]	[Reference]
Yes	1.11 (0.80–1.53)	1.01 (0.84–1.22)	0.97 (0.95–0.99)
Respiratory disease			
No	[Reference]	[Reference]	[Reference]
Yes	1.05 (0.92–1.19)	1.10 (0.77–1.56)	1.03 (0.68–1.57)

¹Federal Poverty Level.

self-reported SHS exposure and detectable serum cotinine. The likelihood of exposure differed by age, education level, marital status, and smoking history using both measures. However, there was no statistically significant difference observed in the likelihood of underreporting of nicotine exposure by these factors.

Distribution of serum cotinine levels by self-reported SHS status

For those with detectable serum cotinine, respondents who reported SHS exposure had higher cotinine levels than those who did not (Figure 1). The serum cotinine distribution skewed significantly to the right, with levels ranging between 0.015 and 1520 ng/mL. Respondents reporting SHS exposure had a median serum cotinine level of 0.107 ng/mL, compared with 0.035 ng/mL for those reporting no SHS exposure. This trend persisted for both never smokers and former smokers,

with the latter group showing marginally increased cotinine levels.

In respondents with low serum cotinine levels (0.015–1 ng/mL), 70.3% reported no SHS exposure. In contrast, 27.4% of those with moderate serum cotinine levels (1–3 ng/mL), 34.6% with high levels (3–12 ng/mL), and 55.7% with very high levels (≥12 ng/mL) reported no SHS exposure. It is estimated that approximately 56.6 million adults in the United States underreported their nicotine exposure (Table 4).

Discussion

We conducted this study to assess underreported nicotine exposure among the US adult population who self-identified as noncurrent tobacco users. We discovered that over half of this population had cotinine-assessed nicotine exposure, yet only

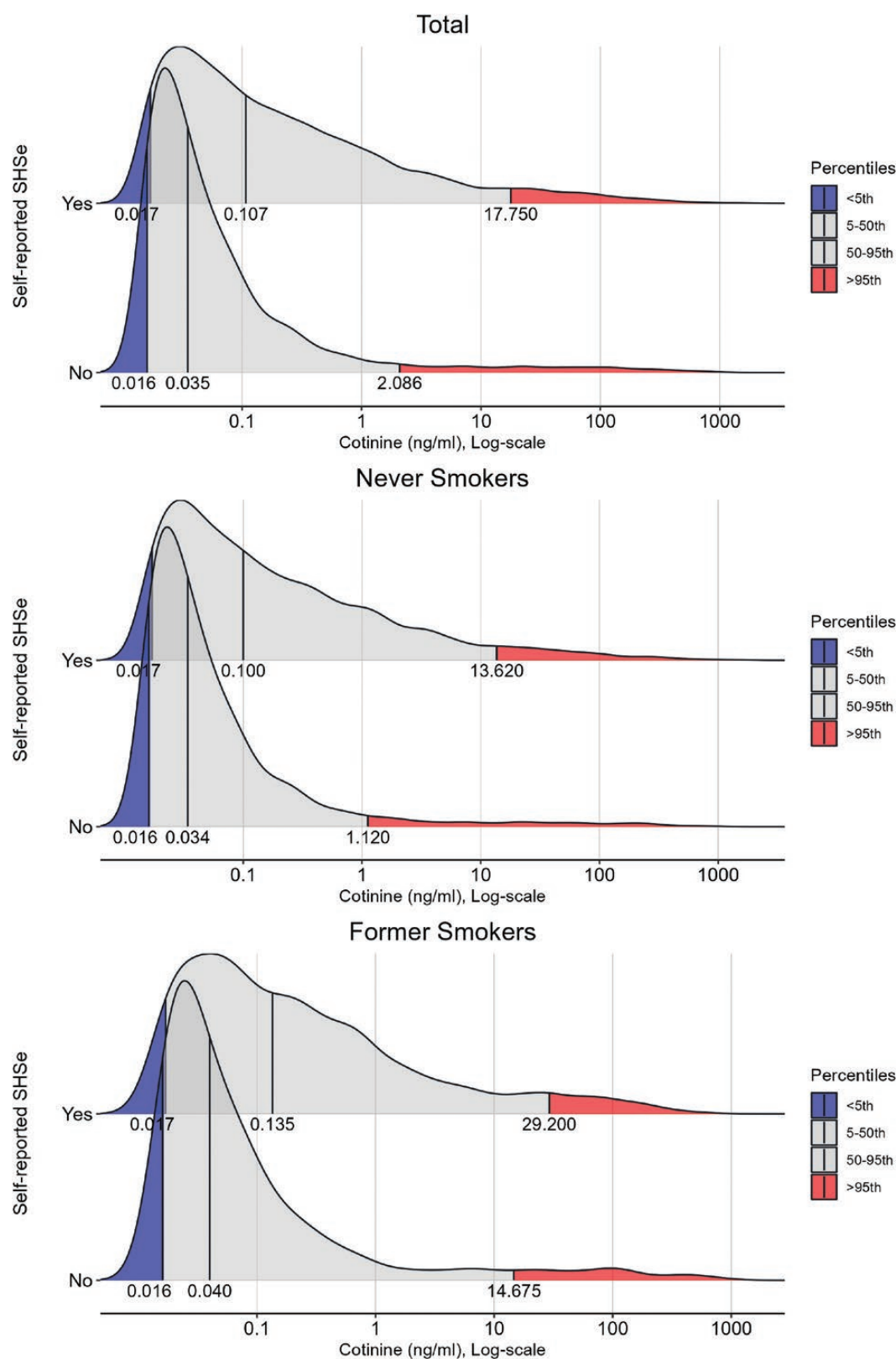


Figure 1. Distribution of serum cotinine levels in respondents with cotinine-assessed SHS exposure, stratified by smoking history.

about one-fifth self-reported SHS exposure. This indicates that nicotine exposure is widely underreported by US adults. While some individuals who reported SHS exposure in the past seven days did not have detectable serum cotinine, most reported no exposure despite having been exposed to nicotine.

Sociodemographic and behavioral correlates, such as age, sex, race and ethnicity, education level, household income, marital status, and smoking history, were identified regardless of self-reported SHS exposure, biomarker-based nicotine exposure, or underreporting of exposure.

Table 4. Respondents Breakdown of Categorization Based on Cotinine Levels and Cross Tabulation with Self-Reported SHS Exposure, NHANES 2013–2020¹

Weighted N; Weighted %	Serum cotinine level (ng/mL)					
	None (Below LLOD)	Low (0.015–1)	Moderate (1–3)	High (3–12)	Very high (≥12)	Had cotinine, total (≥0.015)
Self-reported SHS exposure						
Exposed	8 831 021 11.0%	22 628 369 29.7%	1 914 528 72.6%	1 296 875 65.5%	1 353 800 44.3%	27 193 573 32.4%
Not exposed	71 156 503 89.0%	53 521 687 70.3%	722 895 27.4%	684 737 34.6%	1 704 788 55.7%	56 634 107 67.6%
Total	79 987 524 100%	76 150 056 100%	2 637 423 100%	1 981 613 100%	3 058 588 100%	83 827 680 100%

¹All percentages are weighted column percentages.²Lower limitation of detection.

Findings from this study align with previous research, which suggested that underreporting of tobacco exposure in nonsmokers is more common when exposure levels are low (<0.215 ng/mL).^{15,28} We observed that 70% of individuals with serum cotinine levels lower than 1 ng/mL reported no SHS exposure. Many individuals exposed to SHS may not be aware of its presence if they do not experience symptoms like nasal and eye irritation, respiratory issues, or chest discomfort.^{17,29} Detecting SHS exposure in well-ventilated public places or open spaces can also be challenging, as smoke may dissipate rapidly.^{30,31} However, even advanced dilution ventilation and air-cleaning technologies cannot completely eliminate SHS.³² Thirdhand smoke (ie, residual contamination from tobacco smoke that lingers indoors) can also be inhaled or absorbed through the skin without one's awareness.³³ Hence, when assessing tobacco exposure based on self-reported data, researchers and clinicians should carefully select their measurement tools to accurately capture low-level SHS exposure and fully comprehend the scope of exposure and potential health risks.³⁴

Our findings further support that the burden of SHS exposure is disproportionately distributed among different racial and ethnic groups.²⁷ Non-Hispanic blacks and individuals of other races, including Asian Americans, Native Americans, and Pacific Islanders, who identified as nonsmokers, were over twice as likely to experience nicotine exposure and not report it. In addition to cultural norms, perceptions of SHS exposure can be greatly shaped by an area's tobacco control laws.³⁵ Residents in states with comprehensive, 100% smoke-free laws are more likely to recognize the severe harms of SHS exposure than those with less comprehensive laws.³⁵ Notably, states with the poorest ratings for tobacco control by the American Lung Association often have a higher percentage of black residents than the national average.³⁶ This underscores the need for targeted educational campaigns in these communities and a continued policy push to bridge the legal disparities between states. It is also crucial to expand these policies to encompass all public areas, residential settings, and outdoor venues such as parks, recreational facilities, beaches, outdoor workspaces, and bar terraces.³⁷

One significant strength of our study is its unique focus on investigating and pinpointing underreporting concerning tobacco exposure in a comprehensive US sample. This is crucial

for both scientific research and practical application. Another strength is the nuanced examination of underreporting across demographic variables, smoking history, and biomarker-based exposure levels.

However, our findings should be interpreted with some caution. First, our identification of nonsmokers and those who abstain from all tobacco products relies on self-reported data, which might lead to misclassification and overestimate the unawareness of SHS exposure. We chose not to exclude any participants because there is not a definitive serum cotinine threshold to differentiate smokers from nonsmokers and it is plausible that some nonsmokers were exposed to very heavy tobacco smoke.^{28,38} Although many US epidemiological studies and CDC reports typically classify adults with serum cotinine levels of 10 ng/mL or higher as smokers,^{27,39,40} reviews on SHS exposure biomarkers suggest that nonsmokers exposed heavily to SHS can also show increased serum cotinine.¹⁷ Additionally, no direct correlation exists between the thresholds used for determining smoking status and the agreement between self-reported SHS exposure and cotinine levels.²⁸ Second, NHANES does not collect information about outdoor SHS exposure, which, in specific scenarios, can be comparable to indoor exposure levels.^{31,41,42} This may also result in an underestimation of exposure using self-reported data. Future monitoring efforts should incorporate SHS exposure evaluation in both outdoor and semi-outdoor environments. It is also worth noting that questions assessing exposure to secondhand e-cigarette vapor were not incorporated until the 2017–2020 NHANES survey cycle. This could account for the higher underreporting rates observed in earlier cycles, underscoring the necessity to include such questions as standard items in self-reported SHS questionnaires.

Conclusion

This study found that over one-third of US adults underreported their nicotine exposure. These findings highlight the critical importance of raising public awareness about SHS and the underlying social factors that contribute to this issue. Sustained efforts should be made to enhance public knowledge of SHS and its associated health risks through comprehensive education campaigns,

targeted interventions, and effective public health strategies. Furthermore, additional research is needed to thoroughly investigate the contributing factors that give rise to these discrepancies, including social norms, cultural influences, and individual perceptions. By addressing these knowledge gaps, evidence-based strategies and policies can be implemented to reduce SHS exposure and foster a healthier environment for everyone.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

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Declaration of Interests

None declared.

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Author Contributions

Ruixuan Wang (Conceptualization [Lead], Data curation [Lead], Formal analysis [Lead], Methodology [Equal], Writing—original draft [Lead], Writing—review & editing [Lead]), Jaclyn Hall (Formal analysis [Supporting], Writing—review & editing [Equal]), Ramzi Salloum (Writing—review & editing [Equal]), Frederick Kates (Writing—review & editing [Equal]), Christopher Cogle (Writing—review & editing [Equal]), Adriaan Bruijnzeel (Formal analysis [Supporting], Writing—review & editing [Equal]), Young-Rock Hong (Writing—review & editing [Equal]), and Jennifer LeLaurin (Conceptualization [Equal], Formal analysis [Supporting], Methodology [Supporting], Supervision [Lead], Writing—original draft [Supporting], Writing—review & editing [Supporting]).

Data Availability

The data that support the findings of this study are publicly available at <https://www.cdc.gov/nchs/nhanes/index.htm>.

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