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Prevalence and correlates of secondhand smoke exposure in the home and in a vehicle among youth in the United States

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ABSTRACT

Private settings are major sources of secondhand smoke (SHS) exposure among youth. We measured prevalence and correlates of youth exposures to home and vehicle SHS. The 2016 National Youth Tobacco Survey of U.S. 6th–12th graders was analyzed (n = 20,675). Past-7-day home or vehicle SHS exposures were self-reported. Descriptive and multivariable analyses were performed on weighted data. Among all students, past-7-day SHS exposures were: vehicle (21.4%, 5.56 million); home (21.7%, 5.64 million); home or vehicle (29.0%, 7.50 million); vehicle and home (14.0%, 3.63 million). By household tobacco-use status, home or vehicle SHS exposure was: tobacco-free households, 8.4%; households with combustible-only tobacco users, 59.8%; households with smokeless tobacco/e-cigarette-only users, 21.8%; and households with combined tobacco products usage, 73.9%. Where only the youth respondent but no other household member(s) used tobacco, the measure of association (vs. tobacco-free households) was ~two-fold higher for vehicle SHS exposures (Adjusted Odds Ratio [AOR] = 6.09; 95% Confidence Interval [CI] = 4.93–7.54 than for home SHS exposures (AOR = 3.16; 95%CI = 2.35–4.25). Conversely, where only household member(s) but not the youth respondent used tobacco, the measure of association was over two-fold higher for home SHS exposures (AOR = 22.15; 95%CI = 19.12–25.67) than for vehicle SHS exposure (AOR = 7.91; 95%CI = 6.96–8.98). In summary, nearly one-third of U.S. youth (7.50 million) were exposed to either home or vehicle SHS. Among non-tobacco-using youth with tobacco-using household member(s), the home was a dominant SHS exposure source; among tobacco-using youth with non-tobacco-using household member(s), a vehicle was a dominant exposure source, possibly peers'. Smoke-free environments, including homes and cars, can reduce youth SHS exposure.

1. Introduction

Exposure to secondhand smoke (SHS) causes significant disease and death, including ear infections, more frequent and severe asthma attacks, respiratory infections, and Sudden Infant Death Syndrome among infants and children (US Department of Health and Human Services, 2014a; US Department of Health and Human Services, 2014b). Over the past two decades, an increasing number of states and localities have implemented comprehensive smoke-free policies prohibiting smoking in public places, including all indoor areas of worksites, restaurants, and bars (Centers for Disease Control and Prevention, 2011; Tynan et al., 2016). As of December 2017, the proportion of the U.S. population protected by a comprehensive state or local smoke-free law was nearly 60% (Tynan et al., 2016), and marked declines have occurred in population level SHS exposure (Centers for Disease Control and Prevention, 2010; Homa et al., 2015; McIntire et al., 2014).

Despite this progress in reducing SHS exposure in indoor public places, private settings such as the home and family vehicle still remain as primary sources of SHS exposure, especially among youth (Centers for Disease Control and Prevention, 2010; US Department of Health and Human Services, 2006). Children generally spend more time at home and in other private settings than elsewhere; for example, only about 14% of total hours in a year are spent within the school environment among U.S. youth enrolled in public schools (National Center for Education Statistics et al., 2008). However, children and youth have limited control over their own exposures to SHS within such private settings. The extent of SHS exposure among this population might be increased by the relatively confined nature of private spaces and the longer durations of exposure (US Department of Health and Human Services, 2006; US Department of Health and Human Services and US

Abbreviations: E-cigarettes, Electronic cigarettes; SHS, Secondhand smoke; SHA, Secondhand aerosol; CI, Confidence interval; AOR, Adjusted odds ratio

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Department of Health and Human Services, 2010). Exposure can be particularly high in enclosed environments such as vehicles; a previous study demonstrated that smoking in a car yields unsafe levels of SHS contaminants such as fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), and nicotine, especially for children, even under realistic ventilation conditions (Sendzik et al., 2009; Rees and Connolly, 2006; Semple et al., 2012; Vardavas et al., 2006). Another study found that the average level of polycyclic aromatic hydrocarbons (PAH), a by-product of burning tobacco products, is markedly higher in vehicles than in enclosed public places such as bars and restaurants (Northcross et al., 2014).

A basis for concern about SHS in children is the negative effect of such exposure on their health. Neurotoxic substances such as lead, arsenic, and several other heavy metals are present in SHS, and could potentially impair cognitive development and functioning in children (US Department of Health and Human Services, 2006). Other SHS-attributable conditions in children such as respiratory infections, ear infections, and asthma attacks (US Department of Health and Human Services, 2006) could require outpatient visits or hospitalizations, potentially contributing to school absenteeism. Although most US households reported having smoke-free home rules (80.3% in 2010–2011), millions of youth still are exposed to SHS in private areas. Poor enforcement of voluntary smoke-free rules, coupled with SHS incursion from neighboring units, could result in involuntary SHS exposure among infants and children (Centers for Disease Control and Prevention, 2010; Homa et al., 2015).

There is paucity of recent, nationally representative surveillance data on extent of exposure to SHS among youth within the home and in a vehicle. Despite the fact that the U.S. tobacco product landscape has diversified to include emerging combustible and electronic products (US Department of Health and Human Services, 2012; US Department of Health and Human Services, 2016), conventional cigarettes and other combustible products are still commonly used by U.S. adults overall, including parents living with their dependents (Wang et al., 2018; Agaku et al., n.d.). Thus, timely surveillance data is critical to inform tobacco prevention and control programs aimed at protecting youth from involuntary SHS. To address this gap, this study measured youth exposures to home and vehicle SHS, and explored correlates of exposure among youth using data from the 2016 National Youth Tobacco Survey (NYTS) among U.S. 6th–12th graders.

2. Methods

2.1. Data source, target population, and sampling

NYTS is a nationally representative, school-based, paper-and-pencil survey of U.S. middle (grades 6–8) and high (grades 9–12) school students attending both public and private schools (Centers for Disease Control and Prevention, n.d.-a). A three-stage cluster sampling procedure (county, school, and class) was used to generate a probability sample; a total of 20,675 eligible students completed the 2016 NYTS, yielding an overall response rate of 71.6%. The NYTS sampling frame excluded schools operated by the Department of Defense, Bureau of Indian Affairs, and state Departments of Juvenile Justice Center.

2.2. Measures

2.2.1. Home and vehicle secondhand smoke exposures

Participants were asked: “During the past 7 days, on how many days did someone smoke tobacco products in your home while you were there?”; “During the past 7 days, on how many days did you ride in a vehicle when someone was smoking a tobacco product?” Numerical response options ranged from zero to seven. Respondents who indicated any response other than “0” were considered to be exposed to SHS in the past 7-days. Exposures were also classified as daily (all 7 days) or non-daily (1–6 days). Respondents were expected to report their exposure to smoke from combustible tobacco products specifically, and not to report exposure to secondhand aerosol (SHA, or vapor) as it was assessed with separate questions.

2.2.2. Household tobacco product type, number of product used, and user identity

We defined a household as comprising the individual youth respondent and “anyone who lives with [them] now”. Household tobacco product use status thus accounted for self-reported past-30-day (current) tobacco product use by the youth respondent and proxy-reported use among household member(s) for six combustible tobacco products (i.e., cigarettes, cigars, roll-your-own tobacco, hookahs, bidis, and pipes), as well as smokeless tobacco, and e-cigarettes. Using these data, we created four household types where the respondent and/or their household member(s) used: (1) no tobacco product; (2) only combustible tobacco products; (3) only smokeless tobacco or e-cigarettes and (4) a combination of combustible tobacco products, smokeless tobacco products, and/or e-cigarettes. Any of the latter three categories were considered to be a household with any tobacco product user.

The number of tobacco product types was assessed by counting the distinct product types used by the respondents and/or their household member(s) (cigarettes, cigars, roll-your-own tobacco, hookahs, bidis, pipes, smokeless tobacco, and/or e-cigarettes). The number ranged from zero to eight. We assumed that this measure could be used as a proxy indicator of the tobacco product dose used by household member (s).

Tobacco product user identity in the household was classified as: youth respondent only, household member(s) only, and both youth respondent and household member(s).

2.2.3. Other covariates

Other covariates included: past-30-day SHS exposure in a public place; past-30-day e-cigarette SHA exposure in a public place; and perceived harmfulness of SHS exposure. Assessed socio-demographic characteristics included: race/ethnicity, school level, and sex.

2.3. Analyses

We computed overall and stratified percentages of youth who reported SHS exposures in the home; a vehicle; the home or a vehicle; and both the home and a vehicle. Population counts were also extrapolated from probability weights. Statistical testing within groups was performed with a standard or trend chi-squared test as appropriate. Prevalence estimates with relative standard errors of > 30% were suppressed.

A multivariable logistic regression model was fitted to measure correlates of SHS exposure in the four settings assessed (home, vehicle, either, or both). Predictor variables assessed included: SHA exposure in public places, SHS exposure in public places, perceived SHS harm, school level, race/ethnicity, and household tobacco product user identity. Regression analyses were also used to examine the relationship between the number of tobacco product types used by household member(s) and SHS exposure among youth. All analyses were weighted to yield nationally representative estimates, and performed with R.V.3.2.4.

3. Results

Among U.S. middle and high school students in 2016, 50.6% were male, 55.8% were in high school, and 52.3% were non-Hispanic white. Overall, 13.2% reported past 30-day use of any tobacco product, and 9.0% reported past 30-day use of any combustible tobacco product.

3.1. Youth secondhand smoke exposure in the home and in a vehicle

Among US middle and high school students, past-7-day SHS

Table 1
Proportion of U.S. middle and high school students that reported past 7-day secondhand smoke exposure in the house and in a vehicle, by smoke-free status of household[a], NYTS, 2016.

				All households		Complete tobacco-free households	Households with any tobacco products used	Households with only combustible tobacco products used	Households with only smokeless tobacco or e-cigarette used	Households with combination of combustible tobacco products, smokeless tobacco, and/or e-cigarette used
				N = 20,675		N = 11,707	*N* = 7117	*N* = 4420	*N* = 783	*N* = 1914
		Sample size (N)	Distribution (%)	% (95% CI)	Population count	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Vehicle										
	Overall	20,607	100.0	21.4 (20.7–22.2)	5,560,863	6.5 (5.5–6.6)	42.9 (40.5–43.3)	40.7 (38.2–42.1)	15.3 (14.5–20.2)	60.1 (57.9–63.3)
Sex	Male	10,438	50.6	20.1 (19.1–21.2)	2,591,483	5.7 (5.0–6.4)	40.3 (38.2–42.4)	37.5 (34.8–40.3)	12.1 (8.0–16.3)	59.2 (55.2–63.2)
	Female	10,082	49.4	22.7 (21.6–23.8)	2,938,395	7.2 (6.3–8.1)	45.4 (43.3–47.4)	43.5 (40.9–46.1)	19.1 (13.7–24.6)	60.8 (57.0–64.7)
School level	Middle	9658	44.2	18.9 (17.8–20.0)	2,148,644	6.0 (5.2–6.9)	40.3 (37.9–42.7)	39.3 (36.2–42.3)	15.9 (10.5–21.3)	59.2 (54.2–64.2)
	High	10,897	55.8	23.4 (22.4–24.4)	3,385,177	6.8 (6.1–7.6)	44.7 (42.8–46.6)	41.9 (39.4–44.3)	14.9 (10.7–19.2)	60.4 (57.0–63.8)
Race/ethnicity	White, non-Hispanic	8141	52.3	23.0 (21.9–24.1)	3,017,643	6.2 (5.3–7.1)	45.3 (43.2–47.4)	46.5 (43.5–49.5)	14.2 (10.3–18.0)	60.6 (57.0–64.2)
	Black, non-Hispanic	3050	12.3	23.4 (21.5–25.4)	697,773	8.6 (7.1–10.0)	45.6 (41.6–49.6)	43.2 (38.8–47.6)	–	65.8 (55.7–75.9)
	Asian, non-Hispanic	1036	3.9	9.4 (7.2–11.7)	93,489	4.7 (2.8–6.5)	23.7 (16.5–30.9)	20.3 (12.3–28.3)	–	41.8 (22.1–61.4)
	Hispanic	5793	25.4	17.5 (16.2–18.8)	1,102,588	6.2 (5.2–7.3)	35.2 (32.3–38.1)	28.8 (25.5–32.1)	19.7 (9.3–30.1)	57.0 (50.9–63.1)
Home										
	Overall	20,607	100.0	21.7 (21.0–22.5)	5,640,494	3.7 (3.2–4.0)	46.0 (44.5–47.5)	50.1 (47.8–51.7)	14.5 (10.4–15.2)	58.3 (56.9–62.4)
Sex	Male	10,438	50.6	20.5 (19.5–21.6)	2,647,075	3.4 (2.8–3.9)	44.7 (42.6–46.9)	47.7 (44.9–50.5)	12.2 (8.2–16.2)	54.9 (50.8–58.9)
	Female	10,082	49.4	22.8 (21.7–23.9)	2,952,881	4.1 (3.4–4.7)	50.7 (48.6–52.8)	52.2 (49.6–54.8)	17.2 (12.4–22.0)	61.7 (57.8–65.6)
School level	Middle	9658	44.2	21.1 (20.0–22.3)	2,402,151	4.6 (3.9–5.4)	48.8 (46.4–51.2)	50.0 (46.9–53.0)	16.4 (11.5–21.4)	66.9 (62.0–71.7)
	High	10,897	55.8	22.1 (21.1–23.1)	3,204,280	3.0 (2.5–3.5)	47.1 (45.3–49.0)	50.2 (47.7–52.7)	12.9 (9.0–16.7)	54.2 (50.7–57.6)
Race/ethnicity	White, non-Hispanic	8141	52.3	22.5 (21.4–23.7)	2,959,349	3.3 (2.6–3.9)	48.1 (46.0–50.2)	54.5 (51.5–57.5)	12.9 (9.4–16.3)	57.6 (54.0–61.3)
	Black, non-Hispanic	3050	12.3	23.6 (21.7–25.5)	704,631	5.8 (4.4–7.3)	50.4 (46.4–54.4)	50.4 (46.0–54.8)	30.1 (15.0–45.2)	56.6 (45.5–67.7)
	Asian, non-Hispanic	1036	3.9	12.3 (9.7–14.9)	121,565	–	45.0 (36.9–53.1)	43.6 (34.2–53.0)	–	59.3 (40.8–77.8)
	Hispanic	5793	25.4	18.3 (17.0–19.6)	1,155,639	3.9 (3.1–4.8)	43.5 (40.5–46.5)	40.7 (37.2–44.3)	16.8 (7.2–26.5)	58.1 (51.9–64.2)
Vehicle or home										
	Overall	20,607	100.0	29.0 (28.2–29.8)	7,504,111	8.4 (7.3–8.6)	57.2 (55.8–58.7)	59.8 (57.7–61.4)	21.8 (19.3–25.4)	73.9 (72.3–77.1)
Sex	Male	10,438	50.6	27.4 (26.2–28.5)	3,508,620	7.4 (6.6–8.2)	55.8 (53.7–57.9)	57.0 (54.3–59.8)	16.9 (12.4–21.5)	72.2 (68.5–75.9)
	Female	10,082	49.4	30.6 (29.4–31.8)	3,947,315	9.3 (8.3–10.3)	61.8 (59.8–63.8)	62.3 (59.7–64.8)	27.5 (21.6–33.4)	75.6 (72.2–79.0)

(*continued on next page*)

Table 1 (*continued*)

				All households		Complete tobacco-free households	Households with any tobacco products used	Households with only combustible tobacco products used	Households with only smokeless tobacco or e-cigarette used	Households with combination of combustible tobacco products, smokeless tobacco, and/or e-cigarette used
				N = 20,675		N = 11,707	*N* = 7117	*N* = 4420	*N* = 783	*N* = 1914
		Sample size (N)	Distribution (%)	% (95% CI)	Population count	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
School level	Middle	9658	44.2	26.7 (25.4–27.9)	3,014,852	8.5 (7.5–9.4)	57.0 (54.6–59.4)	58.4 (55.5–61.4)	22.1 (16.4–27.8)	76.0 (71.5–80.4)
	High	10,897	55.8	30.8 (29.7–31.9)	4,449,517	8.3 (7.5–9.2)	60.2 (58.3–62.1)	60.9 (58.5–63.3)	21.7 (16.8–26.5)	73.0 (69.9–76.0)
Race/ethnicity	White, non-Hispanic	8141	52.3	30.1 (28.9–31.3)	3,939,418	7.9 (6.9–8.8)	59.9 (57.8–62.0)	64.4 (61.5–67.3)	20.4 (16.1–24.7)	74.6 (71.4–77.9)
	Black, non-Hispanic	3050	12.3	31.9 (29.8–34.1)	949,466	11.9 (10.1–13.8)	62.3 (58.5–66.0)	61.7 (57.6–65.9)	36.4 (20.1–52.6)	73.1 (63.5–82.6)
	Asian, non-Hispanic	1036	3.9	17.0 (14.1–19.9)	167,970	5.5 (3.6–7.5)	52.2 (44.3–60.2)	51.4 (42.0–60.7)	–	67.5 (50.6–84.5)
	Hispanic	5793	25.4	25.0 (23.5–26.4)	1,566,934	8.1 (7.0–9.3)	52.9 (49.9–55.9)	48.6 (45.0–52.2)	24.1 (13.3–34.9)	72.3 (66.7–77.9)
Vehicle and home										
	Overall	20,607	100.0	14.0 (13.4–14.7)	3,627,476	1.8 (1.3–1.9)	30.5 (29.2–31.9)	30.8 (28.3–31.9)	8.1 (5.9–10)	44.4 (42.8–48.3)
Sex	Male	10,438	50.6	13.3 (12.4–14.1)	1,699,718	1.7 (1.3–2.1)	29.2 (27.3–31.2)	28.2 (25.6–30.8)	7.5 (4–10.9)	41.8 (37.8–45.8)
	Female	10,082	49.4	14.8 (13.8–15.7)	1,904,412	1.8 (1.4–2.3)	34.0 (32.0–36.0)	33.0 (30.5–35.5)	8.9 (5–12.8)	47.0 (43.0–51.0)
School level	Middle	9658	44.2	13.2 (12.2–14.1)	1,491,002	2.1 (1.6–2.6)	31.9 (29.6–34.2)	30.5 (27.6–33.3)	10.3 (5.8–14.8)	50.2 (45.1–55.3)
	High	10,897	55.8	14.6 (13.8–15.5)	2,115,112	1.5 (1.1–1.9)	31.6 (29.8–33.3)	31.1 (28.8–33.4)	6.2 (3.5–8.9)	41.5 (38.1–44.9)
Race/ethnicity	White	8141	52.3	15.3 (14.3–16.3)	2,000,377	1.6 (1.1–2.0)	33.4 (31.4–35.4)	36.3 (33.4–39.3)	6.7 (3.9–9.4)	43.6 (39.9–47.2)
	Black, non-Hispanic	3050	12.3	15.0 (13.4–16.7)	446,516	2.4 (1.6–3.2)	33.8 (30.0–37.6)	32.0 (27.9–36.1)	–	49.2 (38.0–60.5)
	Asian, non-Hispanic	1036	3.9	4.7 (3.0–6.4)	46,477	–	16.5 (9.9–23.0)	12.5 (5.5–19.5)	–	33.5 (14.2–52.9)
	Hispanic	5793	25.4	10.8 (9.7–11.8)	675,711	2.0 (1.4–2.6)	25.5 (22.8–28.2)	20.4 (17.4–23.5)	–	42.7 (36.5–48.8)

Note: Individuals with indeterminate information for respondent or household tobacco product use status were excluded (n = 1851 persons) from the analyses except among all households. Estimates with Relative Standard Error > 30% were suppressed (−). Although results are presented for only the four largest race/ethnic groups with adequate sample size, all students were included in the analyses.

[a] We defined a household as comprising the individual youth respondent and "anyone who lives with [them] now". Household tobacco product use status thus accounted for self-reported past-30-day (current) tobacco product use by the individual respondent and proxy-reported use among household member(s) for 6 combustible tobacco products (i.e., cigarettes, cigars, roll-your-own tobacco, hookahs, bidis, and pipes), smokeless tobacco, and e-cigarettes.

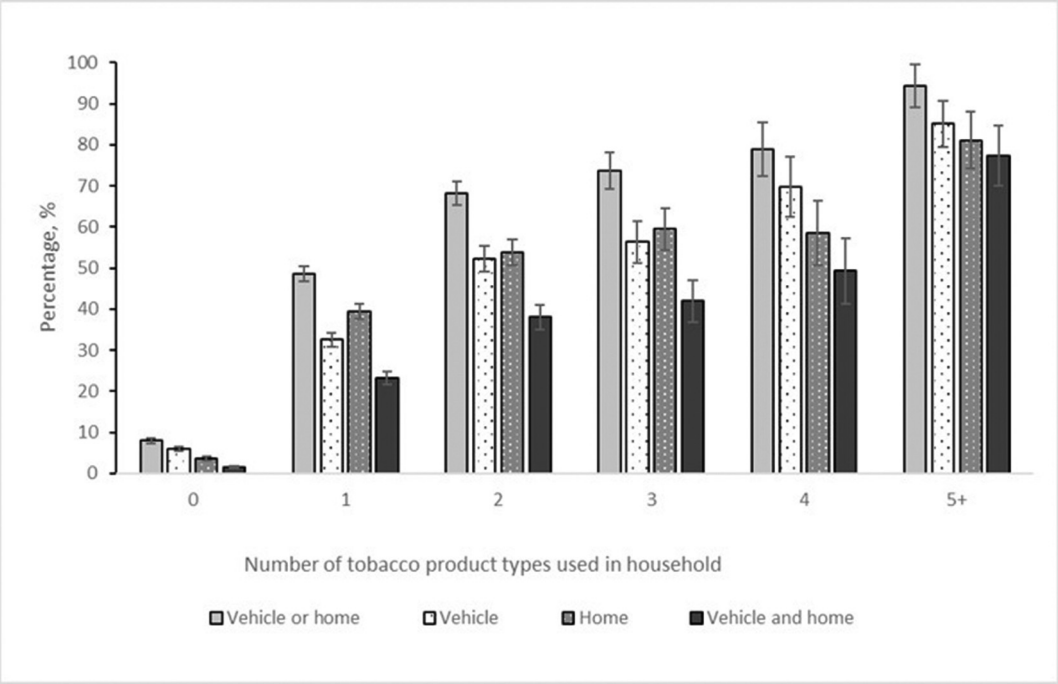

Fig. 1. Number of tobacco product used by household member(s) and secondhand smoke exposure in the past 7 days among U.S. middle and high school students, NYTS, 2016.
Note: NYTS = National Youth Tobacco Survey. The number of distinct tobacco product types was assessed by counting the product types used by the respondents and/or their household member(s) (cigarettes, cigars, roll-your-own tobacco, hookahs, bidis, pipes, smokeless tobacco, and/or e-cigarettes). The number ranged from 0 to 8. The distribution was as follows: 0 products (n = 11,376; 59.4%); 1 product (n = 4775; 25.6%); 2 products (n = 1540; 8.4%); 3 products (n = 607; 3.4%); 4 products (n = 258; 1.5%); and 5+ products (n = 259, 1.6%).

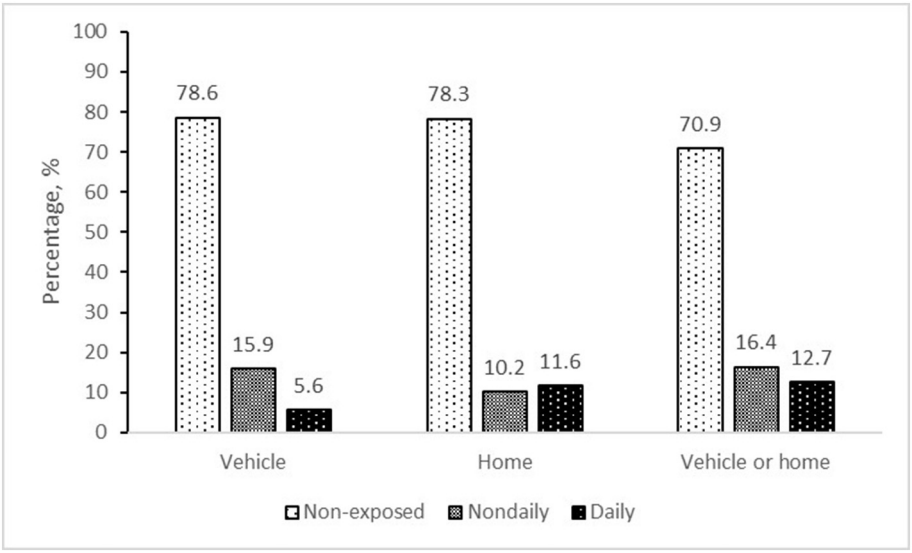

Fig. 2. Proportion of U.S. middle and high school students who reported non-exposure, non-daily exposure, and daily exposure to secondhand smoke in the home and in a vehicle, NYTS, 2016.
Note: NYTS = National Youth Tobacco Survey. Based on self-reported frequency of past 7-day exposure, participants were classified as being exposed daily (all 7 days), non-daily (1–6 days), or non-exposed (0 days).

exposure prevalence estimates were: vehicle (21.4%, 5.56 million); home (21.7%, 5.64 million); home or vehicle (29.0%, 7.50 million); home and vehicle (14.0%, 3.63 million) (Table 1). The prevalence linearly increased with the increased number of tobacco product types used by household member(s) (Fig. 1). Overall prevalence of daily SHS exposure was as follows: vehicle (5.6%); home (11.6%); home or vehicle (12.7%) (Fig. 2).

Distribution of students by household tobacco product use status was as follows: households with no tobacco product user, 61.3%; household with exclusive combustible tobacco product users, 22.7%; households with exclusive smokeless tobacco or e-cigarette users, 4.9%; and households with combined use of different tobacco products, 11.0%. Prevalence of past 7-day home or vehicle SHS exposure was: households with no tobacco product user, 8.4%; households with combustible-only tobacco users, 59.8%; households with smokeless tobacco/e-cigarette-only users, 21.8%; and households with combined tobacco products usage, 73.9%.

Demographic differences in SHS exposure varied by household type (Table 1). For example, in households where combined tobacco products were used, there was consistently no significant racial/ethnic difference in SHS exposure from any source. In households where only combustible tobacco products were used, racial/ethnic differences were observed across all settings, with non-Hispanic whites consistently reporting the highest prevalence of exposure. In households with no

Table 2
Correlates of self-reported home or vehicle secondhand smoke exposure among U.S. middle and high school students, NYTS, 2016.

		Vehicle[a]	Home[a]	Vehicle or home[a]	Vehicle and home[a]
		AOR (95%CI)	AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
Sex	Male	Ref.	Ref.	Ref.	Ref.
	Female	1.03 (0.93–1.15)	1.01 (0.90–1.13)	1.04 (0.94–1.15)	0.99 (0.87–1.12)
	Indeterminate	0.93 (0.47–1.85)	1.40 (0.68–2.88)	1.29 (0.71–2.35)	1.00 (0.44–2.30)
School level	Middle school	Ref.	Ref.	Ref.	Ref.
	High school	1.00 (0.89–1.11)	0.87 (0.78–0.98)	0.98 (0.88–1.09)	0.86 (0.76–0.98)
	Indeterminate	0.86 (0.41–1.81)	0.91 (0.42–1.98)	0.85 (0.43–1.70)	0.88 (0.38–2.01)
Race/ethnicity	White, non-Hispanic	Ref.	Ref.	Ref.	Ref.
	Black, non-Hispanic	1.49 (1.28–1.74)	1.55 (1.31–1.82)	1.70 (1.47–1.98)	1.37 (1.15–1.65)
	Asian, non-Hispanic	0.58 (0.43–0.78)	0.90 (0.67–1.20)	0.84 (0.65–1.09)	0.48 (0.32–0.72)
	Hispanic	0.80 (0.70–0.91)	0.94 (0.82–1.07)	0.91 (0.81–1.03)	0.77 (0.66–0.90)
	Other, non-Hispanic	1.24 (1.02–1.50)	1.50 (1.23–1.82)	1.50 (1.25–1.80)	1.25 (1.01–1.56)
	Indeterminate	1.25 (0.95–1.63)	1.23 (0.93–1.62)	1.23 (0.95–1.59)	1.29 (0.94–1.76)
Perceived SHS harm	No/little harm	Ref.	Ref.	Ref.	Ref.
	Some/a lot of harm	0.91 (0.81–1.03)	0.89 (0.78–1.02)	0.90 (0.80–1.02)	0.88 (0.76–1.01)
	Indeterminate	0.82 (0.49–1.37)	0.67 (0.41–1.10)	0.69 (0.42–1.14)	1.00 (0.57–1.77)
Past 30-day SHS exposure in public	No	Ref.	Ref.	Ref.	Ref.
	Yes	5.07 (4.46–5.77)	3.70 (3.24–4.21)	4.59 (4.09–5.16)	5.11 (4.32–6.04)
	Indeterminate	5.39 (2.53–11.51)	5.23 (2.42–11.31)	5.23 (2.31–11.8)	6.04 (2.42–15.06)
Past 30-day SHA exposure in public	No	Ref.	Ref.	Ref.	Ref.
	Yes	1.44 (1.29–1.62)	1.25 (1.11–1.42)	1.34 (1.2–1.51)	1.43 (1.25–1.64)
	Indeterminate	0.94 (0.47–1.87)	1.62 (0.72–3.64)	1.41 (0.66–3.01)	1.13 (0.46–2.75)
Identity of tobacco users in household[b]	No tobacco user in household	Ref.	Ref.	Ref.	Ref.
	Respondent only	6.09 (4.93–7.54)	3.16 (2.35–4.25)	5.28 (4.31–6.48)	4.88 (3.41–6.99)
	Household member(s) only	7.91 (6.96–8.98)	22.15 (19.12–25.67)	13.84 (12.29–15.59)	20.64 (16.92–25.17)
	Both respondent and household member (s)	17.53 (14.59–21.07)	31.78 (26.05–38.76)	26.32 (21.79–31.79)	37.89 (29.83–48.13)
	Indeterminate	6.83 (5.68–8.20)	11.57 (9.48–14.12)	8.18 (6.88–9.72)	15.22 (11.85–19.54)

Note: Logistic regression model adjusted for all factors listed in Table. Ref = Referent category; AOR = Adjusted odds ratios; CI = Confidence interval; SHS = secondhand smoke; SHA = secondhand aerosol; Indeterminate responses include missing or not sure. NYTS = National Youth Tobacco Survey.

[a] Reported exposure on at least once in the past 7 days.

[b] We defined a household as comprising the individual youth respondent and "anyone who lives with [them] now". Household tobacco product use status thus accounted for self-reported past-30-day (current) tobacco product use by the individual respondent and proxy-reported use among household member(s) for 6 combustible tobacco products (i.e., cigarettes, cigars, roll-your-own tobacco, hookahs, bidis, and pipes), smokeless tobacco, and e-cigarettes.

tobacco product used, race/ethnic differences were also observed across all settings; however, non-Hispanic blacks were now the subgroup consistently reporting the highest prevalence of exposure.

Prevalence of SHS exposure increased by number of products used in the household. Range of past 7-day exposure prevalence in different settings, lower and upper limits being households with 0 vs. ≥5 tobacco products respectively, were as follows: vehicle (6.0% to 85.1%); home (3.6% to 81.1%); home or vehicle (8.0% to 94.4%); home and vehicle (1.6% to 77.3%) (Fig. 2).

3.2. Correlates of Secondhand smoke exposure

The odds of home or vehicle SHS exposure were higher among non-Hispanic blacks (AOR = 1.70; 95%CI = 1.47–1.98) and non-Hispanic other race (AOR = 1.50; 95%CI = 1.25–1.80) when compared to whites (Table 2). Students exposed to SHS in a public place also had 4.59 higher odds (95%CI = 4.09–5.16) of being exposed to home/vehicle SHS compared to those not reporting exposure to SHS in a public place. Similarly, students exposed to e-cigarette aerosol in a public place had 1.34 higher odds (95%CI = 1.20–1.51) of also reporting exposure to home/vehicle SHS. By identity of tobacco user in household, odds of home/vehicle SHS exposure were higher where both household member(s) and youth respondent used tobacco (AOR = 26.32; 95%CI = 21.79–31.79); household member(s) only used tobacco (AOR = 13.84; 95%CI = 12.29–15.59), or youth respondent only used tobacco (AOR = 5.28; 95%CI = 4.31–6.48), compared to when no household member used tobacco products.

The odds of exposure to SHS in both home and vehicle combined, were lower among high school than middle school students (AOR = 0.86; 95%CI = 0.76–0.98). Odds were higher among non-Hispanic blacks (AOR = 1.37; 95%CI = 1.15–1.65) and non-Hispanic other race (AOR = 1.25; 95%CI = 1.01–1.56), but lower among Asians (AOR = 0.48; 95%CI = 0.32–0.72) and Hispanics (AOR = 0.77; 95%CI = 0.66–0.90) than whites. Students exposed in a public place to tobacco SHS (AOR = 5.11; 95%CI = 4.32–6.04) or e-cigarette SHA (AOR = 1.43; 95%CI = 1.25–1.64) had higher odds of reporting combined SHS exposure in home and vehicle than those exposed to the respective emissions in a public place. The odds of reporting combined exposure to SHS in home and vehicle were higher where tobacco was used by both household member(s) and the youth respondent (AOR = 37.89; 95%CI = 29.83–48.13); household member(s) only (AOR = 20.64; 95%CI = 16.92–25.17), or youth respondent only (AOR = 4.88; 95%CI = 3.41–6.99) compared to when no household member used tobacco products.

Table 2 further shows correlates of SHS exposure in the home and in a vehicle separately. Compared to youth reporting no one in their household using tobacco products (referent), youth who used tobacco products themselves (but no other household member used tobacco products) were more likely to be exposed to SHS within the home (AOR = 3.16; 95%CI = 2.35–4.25). Among this group, the corresponding odds ratio for SHS exposure in a vehicle was nearly two-fold higher (AOR = 6.09; 95%CI = 4.93–7.54). Conversely, among youth whose household member(s) used tobacco products (but youth themselves did not use tobacco products), the odds ratio for home SHS exposure was over two-fold higher (AOR = 22.15; 95%CI = 19.12–25.67) than that for vehicle SHS exposure (AOR = 7.91; 95%CI = 6.96–8.98). In all the private settings assessed, there was no significant difference in SHS exposure between the sexes. Similarly, there was no significant difference in SHS exposure within any assessed setting between those who perceived SHS as harmful, and those who did not.

4. Discussion

During 2016, nearly one-third of U.S. youth (7.50 million) reported being exposed to SHS in the past week in either the home or vehicle. The perception that SHS is harmful was not protective against SHS exposure, possibly because youth have very little control over their exposures in these private environments (Centers for Disease Control and Prevention, 2010; US Department of Health and Human Services, 2006); for example, they may not be able to physically remove themselves from places where smoking is occurring. This further aligns with the fact that older youth (high school students) were less likely to report being exposed to SHS in the home, compared to younger-aged individuals (middle schoolers). Youth tobacco users in otherwise tobacco-free households were more likely to be exposed to SHS in a vehicle than in the home, suggestive of exposures in vehicles other than the family car (e.g., among peers). On the other hand, non-tobacco-using youth who lived with tobacco users were more likely to be exposed in the home than in a vehicle, conceivably because of the relatively longer time spent within the home than commuting in a vehicle with family members. The 2006 U.S. Surgeon General's Report concluded that there are no safe levels of exposure to SHS, and that even brief exposures are harmful (US Department of Health and Human Services, 2006).

We observed marked variations in SHS exposure by tobacco product use in the household. Past-7-day home SHS exposure was significantly higher among exclusively smokeless tobacco or e-cigarette using households (14.5%) than in completely tobacco-free households (3.7%); similarly, prevalence was significantly higher in households using a mixture of tobacco product types (58.3%) than those using only combustible products (46.0%). These findings could be explained by the use of combustible tobacco products among users of e-cigarettes and smokeless tobacco products, or potential misclassification of e-cigarette aerosol as tobacco smoke by respondents. Use of multiple tobacco products might also indicate multiple occupants that smoke in the household with a conceivable increase in frequency and intensity of SHS exposure, as also suggested by the linear increases in SHS exposure with the increased number of tobacco product used by household member(s). These findings underscore the importance of assessment of familial tobacco use as a whole to address SHS exposure among youth. A better understanding of exposure patterns can help inform clinical and public health practice, particularly in relation to tobacco screening, counseling, surveillance, and educational programs geared toward youth and their parents.

Intensified implementation of evidence-based interventions is important to continue to reduce population-level SHS exposure, particularly among populations with the greatest burden. At the population level, comprehensive smoke-free laws that prohibit smoking in all indoor areas of worksites, restaurants, and bars can stimulate the adoption of voluntary smoke-free home rules, promote cessation, and normalize smoke-free environments (US Department of Health and Human Services, 2014b; King et al., 2014). Additionally, media campaigns can educate the public about the dangers of SHS exposure and encourage adopting and fully enforcing smoke-free home and vehicle rules, particularly among persons living with children (Centers for Disease Control and Prevention, n.d.-b; Campaign for Tobacco-Free Kids, 2016). Efforts to implement and fully enforce smoke-free policies in private settings are also critical (Campaign for Tobacco-Free Kids, 2016; Association AL, 2017; US Department of Housing and Urban Development, 2017; American Nonsmokers' Rights Foundation, 2017). In addition to voluntary smoke-free vehicle policies, eight U.S. states and Puerto Rico have prohibited smoking in cars with a child passenger (Campaign for Tobacco-Free Kids, 2016). Additionally, smoke-free multiunit housing policies can protect residents from SHS that enters their living units from other units and shared areas in their building (Campaign for Tobacco-Free Kids, 2016; Association AL, 2017; US Department of Housing and Urban Development, 2017; American Nonsmokers' Rights Foundation, 2017). At the individual level, pediatric health providers can address parent/caregiver tobacco dependence as part of pediatric health care. Child wellness visits could be used as opportunities for pediatricians to screen for SHS exposure within private settings and provide parents with education on dangers of SHS exposure and the importance of quitting smoking.

This study is subject to some limitations. First, age-grade standards and the observed associations may not apply to home-schooled youth, or those in special schools not covered by NYTS. More so, NYTS is primarily a tobacco-related survey and no measures of academic achievement such as reading and quantitative skills, or no indexes such as dropout, suspension, expulsion, or graduation were assessed. Second, given the cross-sectional nature of the data, only associations can be drawn because of inability to establish temporality. Finally, there might be residual confounding from the effect of parental socio-economic status given the absence of these data at the individual level. Our findings demonstrate the need for a data source that would allow linkage of SHS, academic performance, and household SES.

5. Conclusion

Nearly one-third of U.S. youth were exposed to either home or vehicle SHS. Among non-tobacco-using youth with tobacco-using household member(s), the home was a dominant SHS exposure source; among tobacco-using youth with non-tobacco-using household member (s), a vehicle was a dominant exposure source, possibly peers'. Comprehensive smoke-free laws, coupled with fully enforced smoke-free home/vehicle rules and population-level education about the harms of SHS exposure, can reduce youth exposure to this preventable health risk. Pediatricians can screen for SHS exposure in the home or family vehicle, provide parents with education on dangers of SHS exposure and the importance of establishing smoke-free home and vehicle rules, which could both protect children from SHS exposure and help smokers quit.

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Table of contents summary

This study assessed prevalence and correlates of vehicle and home secondhand smoke (SHS) exposure among U.S. middle and high school students during 2016.

Contributors' statements

Dr. Agaku conceptualized and designed the study and drafted the initial manuscript.

Ms. Odani helped conceptualize the study, assisted in the statistical analyses and critically reviewed and revised the manuscript.

Dr. Armour and Dr. King helped conceptualize the study and critically reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the U.S. Centers for Disease Control and Prevention.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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