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Short Communication

Tobacco smoke exposure disparities persist in U.S. children: NHANES 1999–2014

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ABSTRACT

Tobacco smoke exposure (TSE) is a common modifiable hazard to children. The objective was to investigate how the prevalence of TSE varied from 1999 to 2014 among U.S. children and to calculate differences between sociodemographic characteristics and TSE by two-year increases. We also assessed associations between sociodemographics and TSE in 2013–2014. A secondary analysis of data from the National Health and Nutrition Examination Survey 1999–2014 was performed including 14,199 children 3–11 years old from nationwide. We conducted logistic regression analyses to assess TSE trends, and associations between sociodemographics and TSE in 2013–2014. TSE prevalence declined from 64.5% to 38.1% during 1999–2014 (a relative reduction of 44.4%). TSE declined among all sociodemographics. In 2013–2014, differences in TSE were found by race/ethnicity, family monthly poverty level [FPL], and house status. Non-Hispanic black children were 1.85 times more likely (95%CI[1.39–2.47]) to be exposed to tobacco smoke than non-Hispanic white children, whereas Non-Hispanic other (OR = 0.71, 95%CI[0.52–0.96]), Hispanic other (OR = 0.42, 95%CI[0.30–0.59]), and Hispanic Mexican (OR = 0.27, 95%CI[0.21–0.35]) children were at lower risk of exposure. Compared to those in the highest FPL category (> 185%), children with FPL ≤130% were 3.37 times more likely (95%CI[2.73–4.15]) and children with FPL 131–185% were 1.80 times more likely (95%CI[1.31–2.49]) to be exposed. Children who lived in rented homes were 2.23 times more likely (95%CI[1.85–2.69]) to be exposed than children who lived in owned homes. Targeted tobacco control efforts are needed to reduce existing TSE disparities among children, especially those who are non-Hispanic black, low socioeconomic status, and live in rented homes.

1. Introduction

Exposure to tobacco smoke among children nationwide is an important public health issue (U.S. Department of Health and Human Services, 2014). Tobacco smoke exposure (TSE), inclusive of cumulative, involuntary secondhand and thirdhand smoke exposure (Jacob et al., 2017), is a common modifiable hazard to children that leads to illness and premature death (U.S. Department of Health and Human Services, 2006). There is no risk-free level of TSE and the only way to protect children's health is to avoid TSE altogether (Farber et al., 2015). A Healthy People 2020 goal is to reduce the amount of TSE to 47.0% in children 3–11 years old (Healthy People 2020, 2018). Despite a national downwards trend in TSE over time (Tsai et al., 2018), nonsmoking children are still regularly exposed especially in private settings such as homes and cars (U.S. Department of Health and Human Services, 2006). Exposed children are susceptible to higher rates of respiratory illnesses, asthma, and ear infections (U.S. Department of Health and Human Services, 2006). School-aged children who live with smokers have increased school absenteeism and the related economic impact regarding caregivers' time to care for absent children is estimated at $227 million per year (Levy et al., 2011). While prior research from 1988 to 2014 has examined TSE among the U.S. nonsmoking population ≥3 years of age (Tsai et al., 2018), little research to date has examined the potential heterogeneity in TSE trends in solely children. More recent investigations are needed to examine if the trends and correlates of TSE identified still exist among children. Consequently, it is unclear if the reduction in TSE over time is equitable among all children and if not, what specific groups should be targeted in future TSE reduction efforts.

The purpose of this study was to investigate how the prevalence of TSE, as measured by serum cotinine, varied from 1999 to 2014 among U.S. children 3–11 years old, and to calculate differences in TSE trends

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Table 1
Tobacco smoke exposure rates as measured by serum cotinine levels by U.S. non-smoking children characteristics, National Health and Nutrition Examination Survey, 1999–2014.

Characteristic	TSE ≥0.05 by NHANES wave										
	1999–2000 (*n* = 1586) n (%)[a]	2001–2002 (*n* = 1817) n (%)	2003–2004 (*n* = 1566) n (%)	2005–2006 (*n* = 1773) n (%)	2007–2008 (*n* = 1795) n (%)	2009–2010 (*n* = 1842) n (%)	2011–2012 (*n* = 1886) n (%)	2013–2014 (*n* = 1934) n (%)	Relative percent decline 1999–2014	OR (95% CI)	p value[c]
Overall TSE	746 (64.5)	860 (56.0)	812 (65.2)	662 (50.9)	722 (53.9)	611 (42.2)	614 (40.6)	608 (38.1)	44.4	0.85 (0.84, 0.86)	
Sex											0.25
Male	392 (64.6)	426 (55.2)	404 (64.8)	320 (47.0)	365 (51.7)	307 (41.9)	315 (40.2)	318 (39.5)	39.5	0.85 (0.84, 0.87)	
Female	354 (64.4)	434 (56.8)	408 (65.7)	342 (55.1)	357 (56.3)	304 (42.5)	299 (41.0)	290 (36.8)	48.4	0.84 (0.83, 0.86)	
Age											0.47
3–5 years	224 (66.3)	264 (60.4)	307 (71.1)	224 (55.3)	208 (53.1)	216 (51.1)	176 (42.2)	186 (40.7)	42.3	0.84 (0.82, 0.86)	
6–11 years	522 (63.9)	596 (54.4)	505 (62.7)	438 (49.3)	514 (54.2)	395 (38.6)	438 (40.0)	422 (37.1)	43.3	0.85 (0.84, 0.86)	
Race/ethnicity											0.92
Non-Hispanic White	157 (63.3)	233 (54.6)	230 (69.1)	196 (51.8)	271 (59.1)	218 (42.0)	137 (37.2)	164 (38.2)	35.8	0.84 (0.83, 0.86)	
Non-Hispanic Black	291 (85.4)	375 (81.6)	365 (81.4)	245 (70.0)	222 (65.0)	176 (67.8)	272 (67.9)	244 (65.9)	24.3	0.87 (0.84, 0.90)	
Non-Hispanic other	23 (60.0)	32 (39.3)	46 (59.4)	56 (51.9)	35 (47.1)	45 (35.3)	61 (39.9)	77 (34.5)	30.9	0.90 (0.86, 0.94)	
Mexican American	231 (49.2)	179 (44.8)	145 (38.7)	141 (32.0)	111 (29.7)	111 (28.3)	85 (29.9)	75 (22.9)	69.5	0.86 (0.83, 0.89)	
Hispanic other	44 (67.9)	41 (46.0)	26 (54.1)	24 (41.2)	83 (49.3)	61 (36.9)	59 (36.1)	48 (32.3)	56.7	0.86 (0.82, 0.90)	
FPL											0.28
≤130%	386 (83.3)	495 (78.0)	428 (75.2)	343 (68.6)	400 (70.6)	351 (56.5)	408 (59.3)	398 (54.0)	39.8	0.80 (0.78, 0.82)	
131–185%	91 (66.1)	92 (61.0)	117 (71.0)	93 (69.8)	99 (64.6)	77 (52.8)	83 (42.9)	67 (37.6)	49.9	0.84 (0.81, 0.87)	
> 185%	166 (46.3)	235 (39.5)	238 (56.8)	204 (39.1)	187 (40.4)	146 (30.2)	92 (23.0)	107 (23.1)	47.3	0.85 (0.83, 0.86)	
Unspecified[b]	103 (68.9)	38 (53.2)	29 (57.5)	22 (45.7)	36 (46.0)	37 (38.2)	31 (39.3)	36 (48.7)	24.6	0.87 (0.83, 0.92)	
Family house status											0.29
Owns home	286 (51.0)	369 (46.8)	350 (60.8)	297 (44.6)	300 (45.4)	224 (32.1)	158 (24.9)	179 (25.4)	52.7	0.83 (0.81, 0.84)	

(*continued on next page*)

Table 1 (*continued*)

Characteristic	TSE ≥0.05 by NHANES wave 1999–2000 (*n* = 1586) n (%)[a]	2001–2002 (*n* = 1817) n (%)	2003–2004 (*n* = 1566) n (%)	2005–2006 (*n* = 1773) n (%)	2007–2008 (*n* = 1795) n (%)	2009–2010 (*n* = 1842) n (%)	2011–2012 (*n* = 1886) n (%)	2013–2014 (*n* = 1934) n (%)	Relative percent decline 1999–2014	OR (95% CI)	p value[c]
Rents home	454 (81.5)	481 (72.5)	450 (71.5)	364 (64.8)	417 (69.9)	381 (57.3)	455 (58.8)	422 (53.5)	38.2	0.84 (0.82, 0.85)	

TSE, tobacco smoke exposure; FPL, family monthly poverty level; OR, odds ratio; CI, confidence interval.
[a] *n* is unweighted and percent is weighted valid percent.
[b] Unspecified refers to don't know and refused to answer.
[c] Sociodemographic variable and NHANES year interaction effects included in the logistic regression model.

between sociodemographic groups. We also assessed the associations between sociodemographics and TSE in 2013–2014 to identify disparities in TSE that may currently exist.

2. Methods

2.1. Participants and procedures

We analyzed data on children 3–11 years old (N = 14,199) from the 1999–2014 National Health and Nutrition Examination Survey (NHANES), a national serial cross-sectional survey conducted by the National Center for Health Statistics. NHANES collects data continuously in two-year waves on the health status of the non-institutionalized U.S. population, selected and recruited by using a complex stratified multistage probability design (Johnson et al., 2013; Centers for Disease Control and Prevention, 2018a). NHANES participation includes a household interview and medical examination where participants ≥3 years old provided a blood sample to measure serum cotinine, which was analyzed via isotope-diluted performance liquid chromatography. Overall response rates for the examined sample for each of the eight waves from 1999 to 2014 was 76.3%, 79.6%, 75.6%, 77.4%, 75.4%, 77.3%, 69.5% and 68.5%, respectively (Centers for Disease Control and Prevention, 2018a).

2.2. Measures

Our outcome variable was serum cotinine, a biomarker of TSE (Benowitz et al., 2009a). Since the NHANES cotinine limit of detections have varied over time from 0.05 ng/ml to 0.15 ng/ml, the present study used the lower cutpoint of 0.05 ng/ml for detection. We performed a sensitivity analysis to assess how many children had > 10 ng/ml, a cutpoint used to define active smoking (Benowitz et al., 2009a). Only 44 children had TSE > 10 ng/ml which did not skew our results and were included since heavy TSE can result in levels > 10 ng/ml in nonsmokers (Benowitz et al., 2009b).

Sociodemographics included sex, age (3–5 and 6–11 years), race/ethnicity (non-Hispanic white, black, other, Mexican American, and Hispanic other), family monthly poverty level (FPL; ≤130%, 131–185%, > 185%, and unspecified), and family house status (owns home or rents home). FPL was calculated by NHANES as the ratio of family income to federal poverty guidelines, and we categorized FPL by using the same cutpoints for determination of financial eligibility for federal programs (e.g., Head Start, Special Supplemental Nutrition Program for Women, Infants and Children).

2.3. Statistical analysis

Using R version 3.3.0, we applied examination weights to account for the complex design and to generalize findings to the U.S. child population (Johnson et al., 2013). We calculated frequency distributions to investigate the prevalence of TSE by sociodemographic characteristics. We calculated relative percent declines from 1999 to 2014 by estimating the mean relative declines in two-years and multiplying these by eight, the total number of two-year periods between 1999 and 2014. Additionally, logistic regression models were built to examine trends in TSE using NHANES waves as a continuous predictor variable. This was done by creating a continuous variable with values from one to eight corresponding to each of the NHANES waves from 1999 to 2000 to 2013–2014 and fitting a model for the presence of TSE in children as the dependent variable and the NHANES wave indicator as the independent variable. Sociodemographics and NHANES waves interaction terms were later entered into these models. Using 2013–2014 wave data only, we built a multivariable logistic regression model to assess the association between sociodemographics and TSE.

3. Results

The overall prevalence of TSE among 3–11 year olds nationwide declined from 64.5% to 38.1% during 1999–2014 (relative decline of 44.4%; Table 1). We observed a reduction in TSE in all sociodemographic groups per each two-year period, with odds ratios (ORs) ranging between 0.80 and 0.90 per each two-year period. Notably, none of the interaction terms between sociodemographics and NHANES waves were statistically significant ($p > 0.05$).

Using NHANES 2013–2014 data to identify potential TSE disparities, multivariable logistic regression results indicate no differences in TSE prevalence based on continuous age (OR = 0.99, 95% confidence interval [CI,0.96–1.02], $p = 0.54$) or males compared to females (OR = 1.17, 95%CI[0.99–1.39], $p = 0.07$). However, significant differences were found between racial/ethnic groups. Non-Hispanic black children were 1.85 times more likely (95%CI[1.39–2.47], $p < 0.001$) to be exposed than non-Hispanic white children, whereas Non-Hispanic other (OR = 0.71, 95%CI[0.52–0.96], $p = 0.03$), Hispanic other (OR = 0.42, 95%CI[0.30–0.59], $p < 0.001$), and Hispanic Mexican (OR = 0.27, 95%CI[0.21–0.35], $p < 0.001$) children were less likely to have cotinine levels indicative of TSE. Children with FPL ≤130% were 3.37 more likely (95%CI[2.73–4.15], $p < 0.001$) and children with FPL 131–185% were 1.80 times more likely (95%CI [1.31–2.49], $p < 0.001$) to be exposed compared to those in the highest FPL category (> 185%). Children living in rented homes were 2.23 times more likely (95%CI[1.85–2.69], $p < 0.001$) to be exposed to tobacco smoke than children who lived in homes that were owned. We replicated these analyses using NHANES 1999–2000 data and found similar results concerning race/ethnicity, FPL, and family house status.

4. Discussion

Our study extends the literature by showing the prevalence of TSE continues to decline among U.S. children ages 3–11 years old (Tsai et al., 2018). This might be attributed to significant progress in tobacco control to reduce caregiver smoking (Centers for Disease Control and Prevention, 2016), including the implementation of comprehensive smoke-free laws and policies, increased tobacco prices and taxes, anti-tobacco advertising, and improved dissemination of evidence-based smoking cessation resources including counseling and medications (U.S. Department of Health and Human Services, 2014). These interventions are likely to have lowered child TSE over time.

Despite the advancements in tobacco control, in 2013–2014, about 14 million (38%) 3–11 year olds remained exposed to tobacco smoke. To date, only about 49% of U.S. individuals are covered by clean indoor air policies prohibiting smoking in specific locations (U.S. Department of Health and Human Services, 2014), and only 61% of children who live with smokers have voluntary home smoke-free rules (King et al., 2016). Further adoption of smoke-free policies, inclusive of all nicotine containing products (e.g., cigarettes, electronic cigarettes), are needed at the home, local, and state levels to protect children (Americans for Nonsmokers' Rights, 2018).

It is important to offer TSE prevention and reduction efforts in multiple venues to expand the reach and implementation of these initiatives. The inclusion of tobacco cessation and TSE reduction efforts by healthcare practitioners in venues highly utilized by at-risk populations (e.g., acute healthcare settings (Lustre et al., 2016)) will help to reduce child TSE. Social service agencies (e.g., 2-1-1 call center (Kegler et al., 2015)) that interact with individuals with disproportionate smoking rates can be trained to implement effective, brief interventions to promote smoke-free homes. Given that a large proportion of school-aged children were exposed to tobacco smoke, another potential venue to offer TSE prevention and reduction intervention efforts is schools. School personnel, including educators and administrators, should be educated on the relationship between home TSE and academic disadvantage (Levy et al., 2011) and should be trained on resources available to promote smoke-free homes.

TSE-related disparities still exist. Similar to prior evidence (U.S. Department of Health and Human Services, 2006; Hiscock et al., 2012), we found that children who were non-Hispanic black and from lower income households had high TSE rates in both 1999–2000 and 2013–2014, indicative that the same disparities have remained over time. This finding aligns with adult current smoking rates that indicate non-Hispanic black adults have high rates of combustible tobacco product use, and a decreasing prevalence of current use of these products as household income increases (Wang et al., 2018). Individuals of lower SES are less likely to quit smoking, resulting in high TSE, as they typically have lower: adherence to treatment; knowledge about the effects of smoking on health; and rates of enforcing smoking bans in their home environments (Hiscock et al., 2012). Additionally, tobacco marketing and the retail environment contribute to disproportionate TSE rates as heavy tobacco advertising and sales are found predominantly in low-income and racial/ethnic neighborhoods, with advertisements tailored towards these groups (U.S. Department of Health and Human Services, 2014; Hiscock et al., 2012).

We also found that children living in rental homes are still more likely to be exposed to tobacco smoke. Many of these children live in multiunit housing (MUH) units where TSE can migrate between units which can expose children to both secondhand and thirdhand smoke exposure (U.S. Department of Housing and Urban Development, 2016). A recommendation to eliminate TSE among those living in MUH is to adopt and enforce a smoke-free policy to protect the health of residents including children. For those without a smoke-free rule, a recommendation to help mitigate the dangers of child TSE in rental homes is to include tobacco-related disclosure policy information when advertising rental properties, and to include information on smoking rules and the potential for TSE to migrate between units in the rental agreement. One intervention that would likely disproportionately benefit this group of children is smoke-free public housing. As of February 2017, the U.S. Department of Housing and Urban Development rule designates that all public housing agencies must implement a smoke-free policy (U.S. Department of Housing and Urban Development, 2016). Additionally, a targeted TSE prevention media campaign that focuses on smoke-free homes would have the potential to reach the audiences needed to decrease related disparities. For example, the Centers for Disease Control and Prevention's Tips from Former Smokers media campaign that focused primarily on smokers was effective in increasing quit attempts and was cost-effective (Centers for Disease Control and Prevention, 2018b). Expanding existing campaigns to primarily focus on TSE and smoke-free homes and tailoring messages to those experiencing TSE-related disparities has major potential to reduce the existing disparities. Future research should examine the impact these efforts will have on future TSE trends among children residing in MUH.

While this study has many strengths including using multiple waves of a nationally representative study of U.S. children and using an objective TSE measure, serum cotinine, that has a half-life of about 16 h (Benowitz et al., 2009a), it is not without limitations. TSE may have been underestimated if exposure is infrequent due to the half-life of cotinine. Response rates slightly varied from 68.5% to 79.6% over the eight waves included in the present study, which may have impacted the observed variations of TSE prevalence. Additionally, potential exposure to electronic cigarette vapor may have influenced serum cotinine levels. It is important to note, however, that electronic cigarettes are relatively newer products (U.S. Department of Health and Human Services, 2014) and current use prevalence estimates among adults is low (2.8%) (Wang et al., 2018). NHANES does not collect self-reported smoking data on participants < 12 years old. Additionally, renting/owning homes was the only consistent housing characteristic for the included NHANES waves, and this question did not distinguish between single-family homes and MUH units.

In conclusion, although TSE has declined from 1999 to 2014, more

targeted tobacco control efforts are needed to reduce TSE disparities that persist among U.S. children to protect their health.

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Conflicts of interest

None

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