



Published in final edited form as:

Nicotine Tob Res. 2025 August 22; 27(9): 1541–1551. doi:10.1093/ntr/ntaf006.

Cotinine-measured secondhand smoke exposure among federal housing assistance recipients without active tobacco or nicotine use in the United States: NHANES, 2007–2018

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Abstract

Introduction: The prevalence of cigarette smoking is high among U.S. Department of Housing and Urban Development (HUD) assistance recipients, putting others at risk for secondhand smoke (SHS) exposure. We evaluated the burden of SHS exposure among HUD-assisted children, adolescents, and adults.

Aims and Methods: Using 2007–2018 National Health and Nutrition Examination Survey (NHANES) data linked with HUD administrative data, we assessed SHS exposure prevalence, defined using serum cotinine, among non-tobacco, non-nicotine-using, HUD-assisted children and adolescents (ages 3–17 years, n=955) and adults (ages ≥18 years, n=878) and among low-income, HUD-unassisted children and adolescents (n=5,788) and adults (n=8,027). Time trends were evaluated. Unadjusted and adjusted multivariable logistic regression models were created to assess SHS exposure by HUD assistance status.

Results: The prevalence of SHS exposure during 2015–2018 was 73.2% [95% CI: 63.2%–81.7%] among HUD-assisted children and adolescents and 50.1% [40.1%–60.1%] among HUD-assisted adults. Decreases in SHS exposure among HUD-assisted individuals from 2007–2010 through 2015–2018 were significant only for ages 12–17 years (78.6% [68.0%–87.0%] to 64.3% [52.5%–74.9%]; $P=0.04$). Among low-income individuals, SHS exposure was higher during 2007–2018 among HUD-assisted than HUD-unassisted children and adolescents (Odds Ratio:

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Disclaimer:

The findings and conclusions in this report are those of the authors and not necessarily the official position of the National Center for Health Statistics, the Centers for Disease Control and Prevention, or the U.S. Department of Housing and Urban Development.

Declaration of Interests: The authors declare they have no conflicts of interest related to this work to disclose.

3.39 [2.58–4.47]) and adults (2.11 [1.66–2.68]). Results remained significant after adjusting for social, demographic, and housing characteristics.

Conclusions: HUD-assisted children, adolescents, and adults had higher exposure to SHS than those not receiving HUD assistance. SHS exposure among HUD-assisted individuals was high for all years studied, compared to published estimates for the general U.S. population, but did decrease among children and adolescents ages 12–17 years.

Implications: This study is the first to provide biomarker-derived prevalence estimates of SHS exposure among recipients of HUD assistance within a nationally representative sample of the United States. The findings suggest that HUD-assisted children, adolescents, and adults are an at-risk population for SHS exposure, independent of known confounding social and demographic factors.

Keywords

NHANES; HUD; housing; public housing; secondhand smoke exposure; serum cotinine; prevalence; housing quality; indoor air quality

INTRODUCTION

Secondhand smoke (SHS) exposure is a major source of morbidity and mortality in the United States, attributing to over 41,000 lung cancer and coronary heart disease deaths annually and associated with numerous health problems such as sudden infant death syndrome, lower respiratory illness, impaired lung function, and middle ear disease in children, stroke, lung cancer, nasal irritation, and coronary heart disease in adults, and low birth weight in pregnant women.^{1,2}

The prevalence of SHS exposure in the United States among people who do not smoke, as measured by cotinine in the blood, declined from 87.5% during 1988–1991 to 25.2% during 2013–2014.³ The prevalence in 2017–2018 was 24.6%.⁴ These declines are believed to be attributable largely to decreasing cigarette smoking rates, increased awareness of the health effects of SHS exposure, and smoke-free laws implemented in various environments.³ However, disparities in exposure to SHS by sociodemographic characteristics have persisted.^{3,5–7} Children and adolescents have a higher prevalence of SHS exposure (35.4% during 2013–2016) than adults (20.8% during 2015–2018) and non-Hispanic Black persons have a higher prevalence of SHS exposure than other race and Hispanic origin groups.^{5,6} SHS exposure increases as family income decreases.^{5,6} Children, adolescents, and adults with annual family income less than 100% of the federal poverty level, defined by the U.S. Department of Health and Human Services, have SHS exposure more than triple that of those with annual family income at or above 400% of the federal poverty level.^{5,6}

SHS exposure also varies by housing characteristics. Historically, the prevalence of SHS exposure has been higher among those who rent than among those who own their home, 38.6% vs. 19.2% among people ages ≥ 3 years who do not smoke during 2013–2014.³ Among children living in households with no people who smoke tobacco, SHS exposure is higher for those living in apartments than those living in detached houses.⁸ Given the

home is the primary source of SHS exposure for children and a major source for adults, many public health interventions have focused on this environment, including mandatory smokefree multiunit and public housing policies, education initiatives, and voluntary smokefree home rules.^{2,9,10}

The U.S. Department of Housing and Urban Development (HUD) is the primary federal agency for assisted housing programs and annually provides rental assistance to approximately 9 million low-income Americans in 4.5 million households. Approximately one-third of these households had at least one child younger than age 18 years.¹¹ People receiving HUD assistance are at high risk of exposure to SHS. The prevalence of cigarette smoking is higher among HUD-assisted adults than among adults overall.^{12–15} Additionally, a high proportion of HUD-assisted households include children, elderly persons, or persons with disabilities, who are especially vulnerable to SHS exposure.¹⁴ Progress has been made in developing and implementing smokefree public health policies in HUD-assisted housing, including the development of guidance for housing agencies and multifamily programs and a smoke-free rule with required implementation by 2018 for all federally supported public housing units.¹⁴ Estimates of SHS exposure at the household level, collected by the American Housing Survey, are self-reported and likely undercount exposure to SHS in the home.¹⁶ Nationally representative biomarker-derived estimates of SHS exposure among HUD participants have not been previously published. Data from the National Health Examination and Nutrition Survey (NHANES) linked to HUD administrative data provide the opportunity to examine the relationship between SHS exposure and HUD assistance using an objective measure. The aim of this study was to assess the prevalence of SHS exposure, as measured by serum cotinine, and any changes over time during 2007–2018 among people in the United States receiving HUD assistance and compare this with low-income individuals not receiving HUD assistance.

METHODS

Data Source

The National Health and Nutrition Examination Survey (NHANES) is a nationally representative, cross-sectional survey designed to monitor the health and nutrition of the civilian, non-institutionalized, resident U.S. population.¹⁷ NHANES is conducted through a household interview and in-person examinations within a mobile examination center (MEC). The survey design has included oversampling of various groups over time, such as Mexican-Americans prior to 2007–2008, Hispanic persons starting in 2007–2008, and non-Hispanic, non-Black Asian persons starting in 2011–2012.^{18,19} Signed informed consent for participation in NHANES was obtained from participants who had reached the age of maturity in their state (usually age 18) and from parents or guardians of participants who had not yet reached the age of maturity. Written consent or assent was additionally obtained from children ages 7–17 years. For most questionnaire items, participants ages ≥16 years were interviewed directly while adult proxies provided information for participants ages <16 years.²⁰ For smoking and recent tobacco use questions, participants ages ≥12 years answered questions themselves without use of proxy.²⁰ Serum was collected from those who participated in the NHANES examination.²¹ The cumulative examination response rate for

all NHANES participants for 2007–2018 was 65.6%, declining from 75.4% during 2007–2008 to 48.4% during 2017–2018.

Data from linkage-eligible NHANES participants during the years 2007 through 2018 were linked with HUD administrative records on public and assisted housing programs for years 1996 through 2019. Participants were considered eligible for linkage if they consented to linkage and provided sufficient data for linkage. Prior to 2009, a refusal to provide a 9-digit social security number was considered an implicit refusal for data linkage.²² HUD data were available through the “NCHS Data Linked to HUD Housing Assistance Program Files”.²³ Data from NHANES participants were linked with HUD administrative data from Housing Choice Vouchers, Multifamily Housing, and Public Housing, HUD’s three largest housing assistance program categories. The percentage of all MEC participants eligible for linkage by survey cycle ranged from 78.5% to 93.8% for survey years used within the analysis.²⁴ Linkage was performed with both deterministic and probabilistic approaches using identifiers, including social security number, name, birth date, sex, and zip code and state of residence.²² Timing of HUD program participation was assessed alongside survey participation to determine concurrency. Additional details about data linkage are available.²² Linkage data and rural-urban coding were available through NHANES Limited Access Data.²⁵ All other data were available through NHANES online public use data. The National Center for Health Statistics (NCHS) Ethics Review Board approved both NHANES and the data linkage between NHANES and HUD.

Definitions

NHANES participants who self-reported active tobacco or nicotine use or who met defined criteria for active tobacco or nicotine use based on serum cotinine level were excluded from analyses. Self-reported active tobacco or nicotine use was defined based on available questionnaire data for those ages 12 years and above as those who smoked at least one cigarette in the last 30 days or used any tobacco or nicotine product in the previous 5 days. Serum cotinine levels were available for NHANES participants ages 3 years and older.²⁶ The lower limit of detection was 0.015 ng/mL. Consistent with prior published U.S. Centers for Disease Control estimates, SHS exposure was defined as a serum cotinine of ≥ 0.05 ng/mL for those ages 3–11 years and 0.05–10.0 ng/mL for those ages ≥ 12 years.^{3,5,6} Those with serum cotinine < 0.05 ng/mL were considered to have no SHS exposure. Individuals ages ≥ 12 years with a serum cotinine > 10 ng/mL were assumed to have active tobacco or nicotine use. Children ages 3–11 years with serum cotinine > 10 ng/mL were rare ($n < 20$), and most of these children were ages < 8 years. These children were assumed to have SHS exposure rather than active or nicotine tobacco use. As the definition for SHS exposure is based on serum cotinine, other secondhand sources of exposure to nicotine beyond tobacco smoke, such as secondhand aerosol from nicotine-containing e-cigarettes will contribute.^{27,28}

Those concurrently receiving assistance from a HUD program at the time of their NHANES examination were defined as HUD-assisted while others were defined as HUD-unassisted.

Various sociodemographic, housing, and survey characteristics were used in analysis: sex (male, female), age (children: 3–11, 12–17 years; adults: 18–44, 45–61, ≥ 62 years), race

and Hispanic origin (Black non-Hispanic, White non-Hispanic, other non-Hispanic, and Hispanic), income to poverty ratio (IPR), education of household reference person for children (categorization based on publicly available data categories: less than high school graduation, high school graduate or some college, college graduate), education for adults (less than high school graduation, high school graduate, some college, college graduate), health insurance (government program, private, none), marital status of household reference person for children or marital status for adults (married or living with partner, widowed or separated or divorced, never married), household size (1 person, 2–4 people, ≥ 5 people), examination season (November–April, May–October), urban-rural classification (urban, rural), 4-year survey cycle (2007–2010, 2011–2014, 2015–2018), and presence of household members who smoke within the home (0, ≥ 1).

Race and Hispanic origin were self-reported and categorized as released by the NHANES survey in four categories: Black non-Hispanic, White non-Hispanic, “other, non-Hispanic,” and Hispanic. Those included in the “other, non-Hispanic” category were persons not of Hispanic origin reporting other races or more than one race. The study design for the included years does not allow for reliable disaggregation of race and Hispanic origin into other categories. Therefore, analyses were limited to the race and Hispanic origin groups included in the NHANES design for all survey cycles used in this analysis. IPR was calculated using the Department of Health and Human Services poverty guidelines, which varies by family size and geographic location.²⁹ Eligibility for HUD assistance is based, in part, on income limits defined by percentage of median family income for the area.³⁰

To improve comparability in income between HUD-assisted and HUD-unassisted individuals, a comparison group of HUD-unassisted individuals included those with an IPR < 2.0 (hereafter referred to as “low-income”).³¹ Differences in income eligibility by location, differences in defining income by IPR vs. percentage of median household income, and additional eligibility criteria for HUD assistance are not accounted for in this categorization scheme. Urban-rural classification was defined according to the 2013 NCHS Urban-Rural Classification Scheme for Counties.³² Urban was defined as residing within one of the four metropolitan county categories (large central metro, large fringe metro, medium metro, or small metro) and rural was defined as residing within one of two nonmetropolitan county categories (micropolitan or non-core).

Statistical Analyses

All analyses were performed using R version 4.0.3 (R Foundation for Statistical Computing), including the R survey package and accounted for the survey’s complex, multistage probability design.³³ Analyses used eligibility-adjusted MEC examination weights which were adjusted for nonresponse to linkage within age, sex, and race and ethnicity domains.²² All linked participants with a probability above a threshold of 0.9225 were included in this analysis.

Prevalence estimates of SHS exposure were calculated during 2007–2010, 2011–2014, and 2015–2018 among 2 groups: 1) HUD-assisted persons and 2) low-income HUD-unassisted persons. Confidence intervals for prevalence estimates were obtained using the Korn and Graubard method.³⁴ Linear and quadratic terms for time trends were assessed using

logistic regression. When quadratic time terms were significant, changes between 2007–2010 and 2011–2014 and between 2011–2014 and 2015–2018 were assessed separately. The relationship of receipt of HUD assistance with exposure to SHS among individuals with low-income was assessed using odds ratios (OR) calculated with bivariate logistic regression as well as multivariable logistic regression to account for potential confounding and mediating variables. Confounding variables were selected a priori including sex, age, race and Hispanic origin, IPR (continuous), education and marital status (of the household reference person for children and adolescents), health insurance status, household size, exam season, urban-rural category, and survey cycle. A sensitivity analysis within the supplementary materials additionally included presence of members of the household who smoke inside the home within the multivariable models as a mediating variable associated with both HUD assistance and exposure to SHS.

Analytic Sample

NHANES participants ages 3 years and older, who were HUD-linkage eligible, were examined in the MEC, and had an available serum cotinine level were included in analysis (Figure 1). Participants with active tobacco or nicotine use were excluded from analyses. Analyses were stratified into two groups: 1) children and adolescents ages 3–17 years and 2) adults ages 18 and above. Because exposure to SHS varies by age,^{5,6} prevalence estimates and time trends were further stratified by age, based on categories often used in HUD reports: 1) 3–11, 2) 12–17, 3) 18–44, 4) 45–61, and 5) ≥ 62 years.^{22,35,36} HUD-assisted individuals were compared with low-income HUD-unassisted individuals, using bivariate and multivariable models and complete case analysis. To further improve comparability between HUD-assisted and unassisted groups, the small number of HUD-assisted participants with an IPR ≥ 2.0 were excluded from models.

RESULTS

Children and Adolescents

Of the 16,653 participants ages 3–17 years examined in the NHANES MEC during 2007–2018, 14,947 (89.8%) were linkage-eligible and had adjusted examination weights available. Among these, 2,969 (19.9%) did not have cotinine data and 429 (2.9%) were excluded for active tobacco or nicotine use. Of the remaining 11,549 children and adolescents ages 3–17 years, 6,743 (955 HUD-assisted and 5,788 low-income HUD-unassisted) were included in analysis while 4,806 (4,055 with HUD-unassisted with IPR ≥ 2 and 751 HUD-unassisted with no IPR data) were excluded (Figure 1). The distribution of social and demographic characteristics among the HUD-assisted and low-income HUD-unassisted groups are shown in Table 1 and Table S1.

The prevalence of exposure to SHS among HUD-assisted children and adolescents did not significantly change from 2007–2010 through 2015–2018 (80.2% [95% CI: 73.2%–86.1%] to 73.2% [95% CI: 63.2%–81.7%], $P = 0.17$; Figure 2A). There was a significant decrease in SHS exposure from 2007–2010 through 2015–2018 among those ages 12–17 years receiving HUD assistance (78.6% [95% CI: 68.0%–87.0%] to 64.3% [95% CI: 52.5%–74.9%], $P = 0.04$) but not among those ages 3–11 years. There was a significant quadratic trend for SHS

exposure from 2007–2010 through 2015–2018 among low-income HUD-unassisted children and adolescents ages 3–17 years and those ages 12–17 years with decreases in SHS exposure from 2007–2010 through 2011–2014 (all ages: 57.4% [95% CI: 51.4%–63.3%] to 46.2% [95% CI: 42.2%–50.1%], $P = 0.01$; ages 12–17 years: 52.2% [95% CI: 44.3%–60.0%] to 39.9% [95% CI: 33.9%–46.1%], $P = 0.01$) followed by no change from 2011–2014 through 2015–2018. For low-income HUD-unassisted children and adolescents ages 3–11 years there was a significant decrease in SHS exposure from 2007–2010 through 2015–2018 (60.6% [95% CI: 54.5%–66.4%] to 50.8% [95% CI: 44.5%–57.1%], $P = 0.02$)

In bivariate analyses of low-income children and adolescents, those receiving HUD assistance were more likely to have exposure to SHS than those not receiving HUD assistance for the entire study period (2007–2018: OR = 3.39 [95% CI: 2.58–4.47]) and for each 4-year period (2007–2010: OR = 3.08 [95% CI: 2.17–4.38]; 2011–2014: OR = 4.02 [95% CI: 2.45–6.60]; 2015–2018: OR = 3.01 [95% CI: 1.77–5.12]; Figure 3A). After adjustment for sociodemographic and other characteristics, this relationship remained significant overall (OR = 1.60 [95% CI: 1.11–2.30]) and for 2007–2010 (OR = 1.82 [95% CI: 1.13–2.95]). Findings remained similar in sensitivity analyses adjusting weights for differential missingness in serum cotinine data by age, sex, and race and Hispanic origin (Figure S1A) and adjusting for presence of people within the household who smoke inside the home (Figure S2A).

Adults

Of the 35,162 participants ages ≥ 18 years examined within the MEC during the study period, 31,845 were linkage-eligible and had adjusted examination weights available. Among these, 1,768 (5.6%) did not have cotinine data available and 8,269 (26.0%) were excluded for active tobacco or nicotine use. Of the remaining 21,808 adults ages 18 years and over, 8,950 (878 HUD-assisted and 8,072 low-income HUD-unassisted) were included in this analysis while 12,858 (11,013 with HUD-unassisted with IPR ≥ 2 and 1,845 HUD-unassisted with no IPR data) were excluded (Figure 1). The distribution of sociodemographic characteristics among HUD-assisted and low-income HUD-unassisted adults are shown in Table 1 and Table S1.

The observed decrease in prevalence of exposure to SHS among HUD-assisted adults was not significant, from 2007–2010 through 2015–2018 among all ages (58.9% [95% CI: 50.7%–66.7%] to 50.1% [95% CI: 40.1%–60.1%], $P = 0.18$; Figure 2B) nor among specific age groups; however, some estimates by time period did not meet NCHS standards of statistical reliability.³⁷ Among low-income HUD-unassisted adults, trends in SHS exposure had a quadratic relationship for all ages combined, those ages 18–44 years, and those ages 45–61 years. Among low-income HUD-unassisted adults in these age groups, decreases in SHS exposure were seen from 2007–2010 through 2011–2014 (all ages: 43.3% [95% CI: 39.9%–46.8%] to 31.6% [95% CI: 28.2%–35.1%], $P < 0.001$; ages 18–44 years: 45.9% [95% CI: 42.5%–49.4%] to 34.5% [95% CI: 29.7%–39.4%], $P < 0.001$; ages 45–61 years: 46.5% [95% CI: 39.3%–53.8%] to 32.2% [95% CI: 27.4%–37.3%]; $P = 0.001$) followed by no change from 2011–2014 through 2015–2018. For ages ≥ 62 years SHS exposure

decreased from 2007–2010 to 2015–2018 (35.8% [95% CI: 31.0%–40.9%] to 24.0% [95% CI: 19.4%–29.0%], $P < 0.001$).

Bivariate analysis showed that adults receiving HUD assistance were more likely to have SHS exposure than low-income adults not receiving HUD assistance during 2007–2018 (OR: 2.11 [95% CI 1.66–2.68]) and for each 4-year period examined (2007–2010: OR = 2.18 [95% CI: 1.49–3.21]; 2011–2014: OR = 2.13 [95% CI: 1.40–3.23]; 2015–2018: OR = 2.23 [95% CI: 1.50–3.31]; Figure 3B). After adjusting for various social, demographic, and survey characteristics, odds ratios were attenuated but remained significant overall (OR = 1.54 [95% CI: 1.20–1.98]), for 2011–2014 (OR = 1.52 [95% CI 1.00–2.32]), and for 2015–2018 (OR = 1.59 [95% CI: 1.04–2.43]). Results did not differ meaningfully when adjusting weights for missingness of cotinine data or for presence of household members who smoke within the home (Figures S1B and S2B).

DISCUSSION

This study is the first to assess prevalence estimates of SHS exposure, using cotinine as a biomarker, among HUD participants within a national survey. Decreases in SHS exposure among HUD-assisted individuals from 2007–2010 through 2015–2018 were significant only for children and adolescents ages 12–17 years. On the other hand, significant decreases in SHS exposure were seen during the study period among all assessed low-income HUD-unassisted age groups, with the largest decreases seen from 2007–2010 through 2011–2014. SHS exposure was higher among HUD-assisted than among low-income HUD-unassisted individuals. Given stable odds ratios over time, SHS disparities by HUD assistance status do not appear to have improved. These results suggest receipt of federal housing assistance may be a risk factor for SHS exposure independent of many known social and demographic confounding factors, including age, race and Hispanic origin, family income, and education level.

The prevalence of SHS exposure among nonsmoking HUD-assisted and low-income HUD-unassisted individuals was higher during 2007 through 2018 compared to previously published estimates among the general U.S. population. SHS exposure among HUD-assisted children and adolescents during 2011–2014 (76.4%) and 2015–2018 (73.2%) was more than double published estimates for all U.S. children (2013–2016: 35.4%).⁶ Similarly, SHS exposure among HUD-assisted adults during 2015–2018 (50.1%) was more than double published estimates among all U.S. adults (20.8%).⁵

There are many potential sources of excess SHS exposure for HUD-assisted individuals. The prevalence of self-reported smoking is higher among HUD-assisted than HUD-unassisted adults.^{14,38} Approximately one-third of HUD-assisted adults actively smoked between 2006 and 2012, nearly double that of the general adult population.^{14,38} While the presence of household members who smoke inside the home was higher among HUD-assisted children and adolescents, and is associated with a high prevalence of SHS exposure, exposure remained higher among HUD-assisted children and adolescents even after adjusting for this in a sensitivity analysis. Counterintuitively, the prevalence of secondhand smoke exposure was higher than the percentage of participants with a household member who smoked inside

the home. This suggests there are other important sources of exposure. For example, if household members avoid smoking inside but instead smoke just outside of their home entry, SHS may intrude inside.⁸ Exposure to residual tobacco smoke chemicals that remain on surfaces, known as thirdhand smoke, can occur after moving into a home previously occupied by a person who smoked or if household members who smoke return to the home with chemicals embedded on their clothing or body.^{4,39,40} Thirdhand smoke exposure is detectable using certain biomarkers, though it is unclear if such exposure would be high enough to qualify as SHS exposure in our study.^{4,40} Those receiving HUD assistance are more likely to live in a building with multiple units, which is associated with higher levels of smoke exposure than detached homes and puts them at risk of SHS intrusion from other units in the building through ventilation systems, shared walls, building cracks, windows, and doors.^{8,41–44} SHS exposure may also occur in multiunit housing common areas when policies restricting smoking in such places do not exist or are not enforced.⁴⁵ SHS exposures in environments outside of the home, such as in cars, other homes, or public places, were beyond the scope of this investigation. Additionally, reported exposure to secondhand tobacco smoke results in higher serum cotinine concentrations than reported exposure to secondhand vaping product aerosols, but we were unable to distinguish SHS exposure from exposure to vaping product aerosols.²⁸

HUD programs are heterogeneous and affected by variable smoke-free policies. A previous analysis found a high prevalence of self-reported cigarette smoking among adults receiving HUD assistance with few differences by HUD program type.¹⁴ While many public housing authorities (PHAs) implemented smoke-free public housing policies prior to the national mandate, all were required to implement such policies by 2018.⁴⁶ The impact of the policy could not be assessed with these data, but this policy is expected to benefit over 1.2 million nonsmoking public housing residents exposed to SHS.⁴⁷ Evaluation of changes to SHS exposure among residents of PHAs which have implemented smoke-free public housing policies have shown variable success.^{41,48,49} Other programs, including Housing Choice Vouchers and Multifamily Housing, may be affected by local smoke-free policies but do not have a national policy. Program-specific estimates were assessed; however, there was insufficient sample size in our study to produce reliable estimates or evaluate changes in SHS exposure in relation to smoke-free policies.

There are at least several limitations of this analysis. First, exclusion of tobacco or nicotine-using individuals was defined, in part, by self-reported tobacco or nicotine use, which may be subject to social desirability bias and underreported. Assuming those with a serum cotinine of >10 ng/mL were active tobacco or nicotine users may help to minimize this bias but may also misclassify some individuals with very high levels of SHS exposure as active tobacco or nicotine users. Second, the relatively small number of linkage-eligible HUD participants in NHANES necessitated combining multiple survey years to produce reliable estimates. However, some estimates still did not meet reliability criteria due to inadequate sample size. Generally, SHS exposure among HUD-assisted individuals was lower in 2015–2018 than 2007–2010 for most age groups; however, trends did not necessarily reach statistical significance likely, in part, due to small sample size. Small sample size also prevented a more in-depth analysis by individual HUD program types. Larger sample sizes were available for the low-income HUD-unassisted comparison group, reflective of

the higher proportion of the U.S. population within this group. These larger sample sizes provided greater statistical power to assess trends in the low-income, HUD-unassisted group than among the HUD-assisted group. Third, the missingness of serum cotinine among some linkage-eligible NHANES participants could lead to bias. However, adjusting weights for missingness did not reveal any appreciable differences in results. Fourth, during 2007–2018 NHANES did not capture characteristics of the home structure (i.e., attached vs. detached). HUD participants are more likely to live in attached housing, and people who live in attached housing are more likely to have SHS exposure.⁴⁴ Fifth, the NHANES sample is designed to be nationally representative of the U.S. population; however, subgroups within the sample may not necessarily be representative. Differences in the sociodemographic composition of each HUD-assisted and HUD-unassisted subgroup may contribute to different results over time. Sixth, IPR cutoff is not a perfect way of defining a comparison group. The HUD-unassisted low-income comparison group is inherently different from the HUD-assisted group by numerous sociodemographic characteristics, making adjusted analysis necessary for informative direct comparisons, though adjustments cannot account for unobserved differences in the groups. Seventh, this study is limited to the years 2007–2018. Newer linked NHANES-HUD data is not available for analysis. Changes in policy and changes during the COVID-19 pandemic are unable to be assessed.

Regardless of the source of exposure, the prevalence of SHS exposure was higher among HUD-assisted individuals, even when controlling for key characteristics. While SHS exposure appears to have decreased among HUD-assisted children and adolescents ages 12–17 years, the prevalence nonetheless remained high, and for age groups there were no significant changes. Findings suggest HUD-assisted children, adolescents, and adults represent an at-risk population which would benefit from continued surveillance. The national smoke-free public housing mandate was not implemented until 2018, the last year studied in this analysis, and would not be expected to be reflected in current results. Future studies could assess the effect of such public health policies on SHS among HUD-assisted individuals, especially by HUD program category.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding:

The authors have no sources of funding to disclose.

Data Availability:

NCHS-HUD Linked Data and geographic NHANES data are restricted-use data and can be accessed through the NCHS Research Data Center (RDC) for those with approved proposals [<https://www.cdc.gov/rdc/index.html>]. Other NHANES data used in the preparation of this manuscript are publicly and freely available without restriction at [<https://www.cdc.gov/nchs/nhanes/index.html>].

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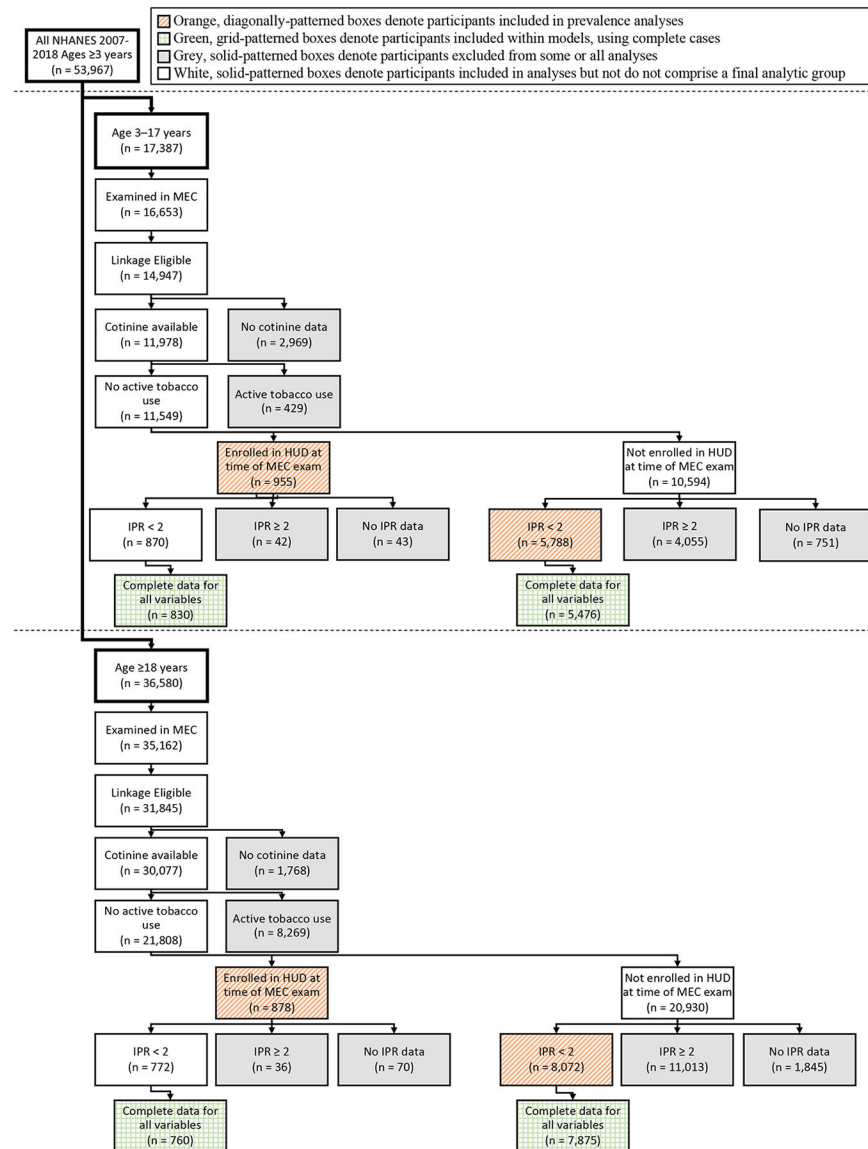


Figure 1. Flow diagram for participant eligibility in included analyses.

NOTE: NHANES, National Health and Nutrition Examination Survey; HUD, U.S. Department of Housing and Urban Development; MEC, Mobile Examination Center; IPR, income to poverty ratio. SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey Data Linked to HUD Housing Assistance Program Files.

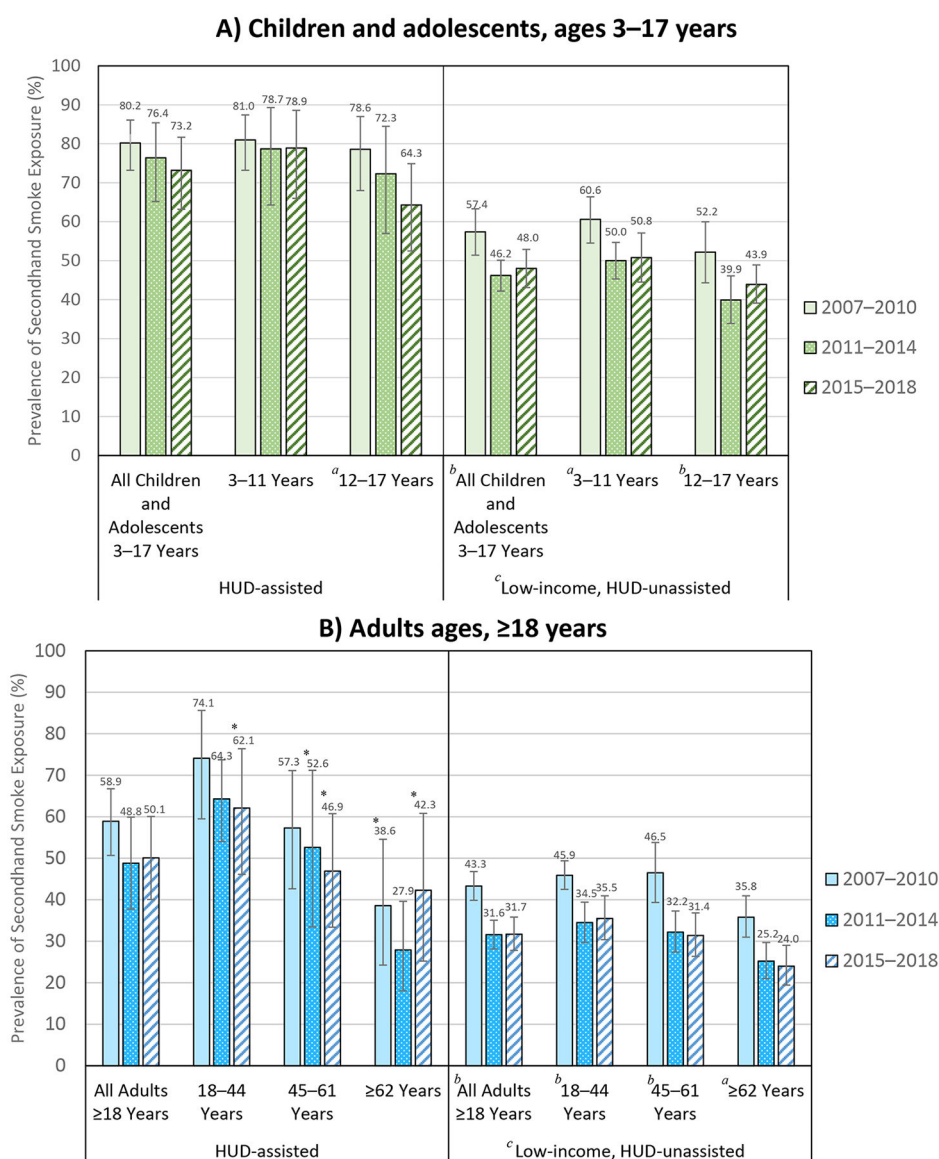


Figure 2. Prevalence of secondhand smoke exposure by HUD assistance status — United States, 2007–2018. (A) Among children and adolescents (3–17 years) without active tobacco or nicotine use. (B) Among adults (≥18 years) without active tobacco or nicotine use.

* Estimate does not meet National Center for Health Statistics standards of reliability.

^a Significant decreasing trend from 2007–2010 through 2015–2018 ($P < 0.05$)

^b Significant decrease from 2007–2010 through 2011–2014 ($P < 0.05$)

^c For group without HUD assistance, inclusion based on low income, defined here as income to poverty ratio (IPR) < 2 .

NOTES: HUD, U.S. Department of Housing and Urban Development; IPR, income to poverty ratio.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey Data Linked to HUD Housing Assistance Program Files.

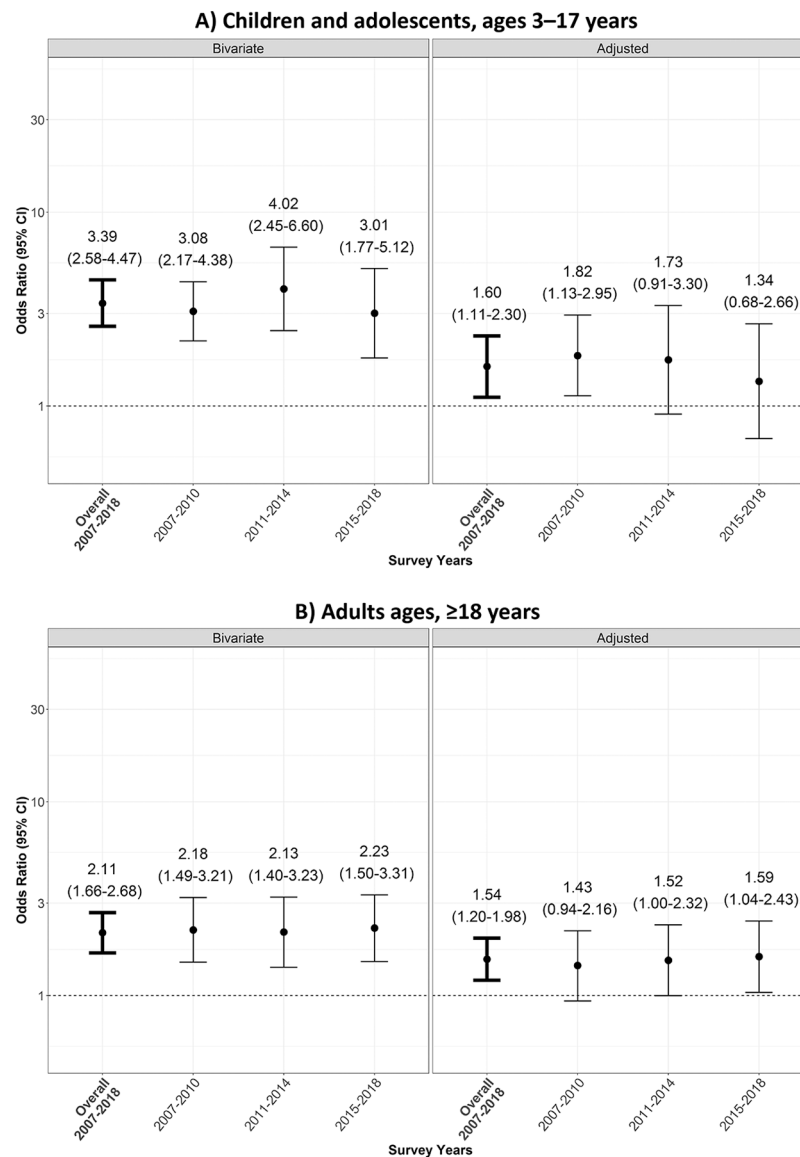


Figure 3. Unadjusted and adjusted odds ratios of secondhand smoke exposure for persons receiving HUD assistance compared with low income persons not receiving HUD assistance — United States, 2007–2018. (A) Among children and adolescents (3–17 years) without active tobacco or nicotine use. (B) Among adults (≥18 years) without active tobacco or nicotine use. NOTES: For all participants, inclusion based on low income, defined here as an income to poverty ratio (IPR) < 2. For children and adolescents, analyses were adjusted for sex, age group, race and Hispanic origin, income to poverty ratio (continuous), education of household reference person, health insurance status, marital status of household reference person, household size, exam season, and urban-rural classification. For overall, model additionally adjusted for survey cycle. For adults, analyses were adjusted for sex, age group, race and Hispanic origin, income to poverty ratio (continuous), education, health insurance status, marital status, household size, exam month, and urban-rural classification. For overall, model additionally adjusted for survey cycle. HUD, U.S. Department of Housing and Urban Development; IPR, income to poverty ratio.

SOURCE: NCHS, National Health and Nutrition Examination Survey Data Linked to HUD Housing Assistance Program Files.

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Table 1.

Unweighted sample sizes (and weighted percentages of total) for children and adolescents ages 3–17 years and adults ages 18 and older without active tobacco or nicotine use, included in NHANES-HUD linked examination data, and with available serum cotinine level — United States, 2007–2018.

	Children and adolescents ages 3–17 years		Adults ages 18 and older	
	Receiving HUD assistance at time of MEC examination	Low-income ^d and not receiving HUD assistance at time of MEC examination	Receiving HUD assistance at time of MEC examination	Low-income ^d and not receiving HUD assistance at time of MEC examination
All [n]	955	5,788	878	8,072
Sex [n (%)]				
Male	475 (49.2%)	2935 (50.7%)	232 (21.3%)	3461 (40.9%)
Female	480 (50.8%)	2853 (49.3%)	646 (78.7%)	4611 (59.1%)
Age group [n (%)]				
3–11 years	662 (64.3%)	3831 (61.0%)	N/A	N/A
12–17 years	293 (35.7%)	1957 (39.0%)	N/A	N/A
18–44 years	N/A	N/A	287 (40.1%)	3628 (52.4%)
45–61 years	N/A	N/A	190 (21.6%)	1809 (21.6%)
≥62 years	N/A	N/A	401 (38.3%)	2635 (26.0%)
Race and Hispanic origin group [n (%)]				
Black, non-Hispanic	592 (52.6%)	1288 (15.4%)	381 (40.2%)	1390 (12.1%)
White, non-Hispanic	85 (19.4%)	1412 (39.9%)	160 (29.2%)	2695 (49.7%)
Other, non-Hispanic	82 (7.6%)	554 (8.0%)	123 (11.0%)	870 (8.5%)
Hispanic	196 (20.4%)	2534 (36.7%)	214 (19.6%)	3117 (29.7%)
Income to poverty ratio [n (%)]				
<1.0	661 (73.5%)	2901 (45.7%)	532 (63.4%)	3157 (36.0%)
1.0–1.99	209 (21.7%)	2887 (54.3%)	240 (31.3%)	4915 (64.0%)
≥2.0	42 (4.7%)	N/A	36 (5.3%)	N/A
Education level of household reference person [n (%)]				
Less than high school graduation	284 (30.9%)	2110 (33.1%)	N/A	N/A
High school graduate or some college	623 (65.5%)	3082 (58.2%)	N/A	N/A
College graduate	28 (3.6%)	442 (8.7%)	N/A	N/A

	Children and adolescents ages 3–17 years		Adults ages 18 and older	
	Receiving HUD assistance at time of MEC examination	Low-income ^d and not receiving HUD assistance at time of MEC examination	Receiving HUD assistance at time of MEC examination	Low-income ^d and not receiving HUD assistance at time of MEC examination
Education level of adult participant [n (%)]				
Less than high school graduation	N/A	N/A	355 (36.6%)	2898 (27.9%)
High school graduate	N/A	N/A	227 (28.2%)	1999 (26.6%)
Some college	N/A	N/A	224 (27.4%)	2254 (31.9%)
College graduate	N/A	N/A	67 (7.8%)	915 (13.6%)
Survey Cycle [n (%)]				
2007–2010	305 (34.0%)	1854 (31.4%)	230 (25.7%)	2679 (30.7%)
2011–2014	355 (35.8%)	2112 (35.0%)	325 (38.8%)	2747 (36.2%)
2015–2018	295 (30.2%)	1822 (33.6%)	323 (35.4%)	2646 (33.2%)

^a For group without HUD assistance, inclusion based on low income, defined here as income to poverty ratio (IPR) < 2.

NOTE: Sample sizes presented comprise the analytic sample for prevalence measures. Sample sizes included in logistic regression models are smaller given complete case analysis used (see Figure 1). N/A, Not applicable to participant group.

SOURCE: NCHS, National Health and Nutrition Examination Survey Data Linked to HUD Housing Assistance Program Files.