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RESEARCH ARTICLE

Healthcare Costs of Secondhand Smoke Exposure at Home for U.S. Children

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Introduction: The purpose of this study is to estimate healthcare utilization and healthcare costs due to secondhand smoke exposure at home for children in the U.S.

Methods: Using data from the 2000, 2005, and 2010 U.S. National Health Interview Surveys, the authors analyzed the association between secondhand smoke exposure at home and utilization of three types of healthcare services (hospital nights, emergency room visits, and doctor visits) for children aged 3–14 years (N=16,860). A zero-inflated Poisson regression model was used to control for sociodemographic characteristics and the number of months without health insurance. The authors determined excess healthcare utilization attributable to secondhand smoke exposure at home for children and then estimated annual secondhand smoke–attributable healthcare costs as the product of annual excess healthcare utilization and unit costs obtained from the 2014 Medical Expenditures Panel Survey. This study was conducted from 2016 to 2018.

Results: The prevalence of secondhand smoke exposure at home for children in 2000, 2005, and 2010 was 25.0%, 12.3%, and 9.1%, respectively. Secondhand smoke exposure at home was positively associated with emergency room visits, but was not significantly associated with nights at the hospital or doctor visits for children. Secondhand smoke exposure at home for children resulted in an excess of 347,156 emergency room visits in 2000, 124,412 visits in 2005, and 101,570 visits in 2010, which amounted to $215.1 million, $77.1 million, and $62.9 million in excess annual healthcare costs (2014 dollars) in 2000, 2005, and 2010, respectively.

Conclusions: Although U.S. healthcare costs attributable to secondhand smoke exposure at home for children are declining, interventions to reduce secondhand smoke exposure at home for children are still needed to reduce the economic burden attributable to secondhand smoke exposure.
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INTRODUCTION

Secondhand smoke (SHS) exposure, also known as passive smoking, is made up of side stream smoke from the burning tip of the cigarette and mainstream smoke drawn through the cigarette and exhaled by the smoker.[1] SHS exposure has several adverse health effects on children, including ear infections, asthma, respiratory symptoms, respiratory infections (bronchitis and pneumonia), sudden infant death syndrome, and attention-deficit hyperactivity disorder.[2–4]

Several studies have shown that SHS exposure leads to significant economic burden for children in the U.S. A study published in 1987[5] estimated that the annual

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SHS-attributable healthcare cost for emergency room (ER) visits was $92 per family for children with asthma who lived with at least one smoker. Another study conducted in 2015[6] found that the total costs for children (aged 3−19 years) exposed to SHS in public housing, using biomarker-measured exposure, was $96 million, which accounted for 53% of total medical and nonmedical costs. Another study[7] found that expenditures for Medicaid children (aged 0−11 years) who lived with smokers were an average of $10 higher for ER visits per child per year than those who did not live with smokers ($58 versus $48) from 2000 to 2007. In California, the SHS-attributable healthcare costs for children (aged 3−14 years) who were exposed to SHS at home totaled nearly $7.7 million in 2009.[8]

Although the prevalence of SHS exposure at home for children, based on parent/guardian report, has declined from 24.7% in 2000 to 8.2% in 2010,[9] 14% of U.S. households did not have 100% smoke-free rules at home in 2014/2015.[10] As a result, many children potentially are still exposed to SHS in their homes. Children's lungs and respiratory tracts are still developing and thus are more susceptible to toxins from SHS, so they are more vulnerable to the effects of SHS than other population groups.[1] In addition, children have a higher respiration rate per body weight and lung surface area, so SHS exposure has more adverse effects on children than on adults in the same environment.[1] Furthermore, children (particularly infants) tend to spend more of their time indoors and may be unable to remove themselves from exposure to SHS. As a result, the home setting is still the primary source of SHS exposure for children.

No previous study estimated national costs attributable to SHS for children exposed in the home environment in the U.S. This information is needed to inform policy development related to SHS exposure, including encouraging individuals to implement smoke-free home rules. To fill this gap, the aim of this study is to estimate annual healthcare utilization and costs attributable to SHS exposure at home for children in the U.S.

METHODS

This study was conducted from 2016 to 2018. Two data sources were used. The National Health Interview Survey (NHIS) is a nationally representative household face-to-face interview survey of ≅100,000 people conducted annually since 1957. In each sampled household, one adult and one child are randomly selected to provide detailed health information. For children, a knowledgeable adult (usually a parent) in the household answers questions about the child. The NHIS Sample Child file contains information on children's healthcare utilization and sociodemographic characteristics. The Person file provides information on the number of months without any health insurance coverage. In addition, a Cancer Control Supplement has been conducted for core NHIS adult participants every 5 years since 2000. This Supplement contains detailed questions about tobacco use and SHS exposure at home. The questions on SHS exposure at home were asked in the Cancer Control Supplement in 2000, 2005, and 2010. Unfortunately, the SHS questions were not included in the 2015 NHIS Cancer Control Supplement. The authors merged the Cancer Supplement and Sample Child files to obtain SHS exposure status at home for children. Then, the 2000, 2005, and 2010 data were pooled to obtain a large enough sample for analyzing the association between SHS exposure at home and healthcare utilization.

The other data source used is the Medical Expenditures Panel Survey (MEPS), a nationally representative face-to-face household interview survey of the U.S. civilian non-institutionalized population. MEPS collects each survey individual's healthcare utilization and expenditures, payment sources, health status, and health insurance coverage. For children aged 3−14 years, the authors used the 2014 MEPS data (the most recent available data when this study was conducted) to calculate unit cost per hospital day, per ER visit, and per doctor visit caused by any medical conditions regardless of whether they were SHS-related diseases .

Study Sample

This study focused on children aged 3−14 years. Children aged 0−2 years were excluded to separate the health effects of home exposure from maternal smoking during pregnancy. Children aged 15−17 years were also excluded to avoid confounding from smoking-attributable healthcare costs given that many of these older teens are active smokers. The pooled sample from the 2000, 2005, and 2010 NHIS data contained 18,466 children. After excluding 1,606 (8.7%) respondents with missing information on parents' highest education level or any of the healthcare utilization variables (hospital nights, ER visits, and doctor visits), the final study sample contained 16,860 children aged 3−14 years.

Measures

The dependent variables were three types of healthcare utilization: (1) the number of nights in the hospital in the past 12 months, (2) the number of ER visits in the past 12 months, and (3) the number of doctor visits in the past 2 weeks.

The key independent variable was the status of SHS exposure at home. Children were considered to be exposed to SHS at home if they lived in a household where an adult reported that any residents smoked inside the home >1 day per week. This was based on the questions, *In a usual week, does anyone who lives here, including yourself, smoke cigarettes anywhere inside this home?* and *Usually, about how many days per week do people who live here smoke anywhere inside this home?*

Other covariates in this study included sociodemographic characteristics: age (3−5, 6−11, and 12−14 years), sex (male and female), race and ethnicity (non-Hispanic [NH] white, NH African American, NH Asian, NH other, and Hispanic), parents' highest education level (less than high school diploma, high school graduate/GED, some college, and college degree or higher), and household poverty status based on federal poverty level (FPL) guidelines (poor [<100% FPL], low income [100%−199% FPL], middle income [200%−399% FPL], and high income [≥400% FPL]. For household poverty status, a category of unknown was included because 14.6% of children lived in households that had unknown

income status and there was concern that income might not be missing at random. The number of months without health insurance in the past 12 months was also included in the model, measured by two questions: *In the past 12 months, was there any time when you did not have any health insurance or coverage?* and a follow-up question for those who answered in the affirmative: *In the past 12 months, about how many months were you without coverage?* Finally, the survey year (2000, 2005, and 2010) was included.

Statistical Analysis

Three measures were estimated for all children by SHS exposure status for each type of healthcare service: (1) the mean healthcare utilization per child among all children (whether they used the service or not), (2) the mean healthcare utilization per child among those with at least one night/visit, and (3) the proportion of children having at least one night/visit. The authors tested the difference in the mean utilization per child between exposed and unexposed children using a bivariate linear regression model for the first two measures. For the third measure, a chi-squared test was used to test the difference between exposed and unexposed children in the proportion using at least one service .

An econometric model was used to analyze the association of SHS exposure at home with each healthcare utilization dependent variable. Because each dependent variable is a count variable containing many zero values (95.6% for hospital nights, 81.2% for ER visits, and 88.5% for doctor visits), the authors explored several model specifications that deal with such distributional characteristics including a two-part model, Poisson regression model, negative binomial regression model, zero-inflated Poisson (ZIP) regression model, and zero-inflated binomial regression model. From goodness of fit (the log-likelihood ratio, Akaike information, and Schwarz information criteria)[11] and root-mean square error tests, the ZIP regression model was chosen.[12,13]

The ZIP model takes into account two types of zeros.[11] One is *sure zeros* for those who would never choose to use healthcare services even if they were ill or injured. The other is *regular zeros* for those who do not use healthcare services because they are not ill or injured. The ZIP model has two components: the first is estimated by a logit model. It generates the sure zero cases for children who would not be expected to use healthcare even if they were ill or injured. The second component is estimated by a Poisson model. It predicts the natural log of the number of healthcare service encounters for those children without sure zero utilization based on a Poisson distribution. The counts in the second process include children who do not use healthcare utilizations because they are not ill or injured (regular zeros), and children who had one or more episodes of utilization. A separate ZIP model was estimated for each healthcare utilization measure. To facilitate interpretation of results, the authors reversed the signs of the coefficients in the first component so that they indicate the probability of having a regular zero or positive healthcare utilization when the child is ill or injured. The exponentiated coefficients are reported for the Poisson model in the second component to make the results easier to interpret.

For each healthcare utilization dependent variable, if neither of the two components in the ZIP model showed a statistically significant coefficient for the SHS exposure variable, the SHS-attributable healthcare utilization was assumed to be zero. If either of the two components showed a statistically significant coefficient for the SHS exposure variable, the SHS-attributable healthcare utilization was determined by an "excess utilization" approach. This approach involved generating two sets of predicted healthcare utilization for each exposed child: one under the factual case, and the other under the counterfactual case. The factual predictions reflect all the characteristics of each of these exposed children. The counterfactual predictions are calculated for exposed children under a hypothetic scenario in which they are assumed not to be exposed to SHS at home while all other characteristics (including sociodemographic characteristics and number of months without health insurance coverage) are held the same. The difference between the factual and counterfactual predictions is the excess healthcare utilization attributable to SHS exposure.

The SHS-attributable healthcare costs are the product of the attributable healthcare utilization and the unit cost for each type of healthcare utilization (per hospital night, per ER visit, or per doctor visit) estimated from the 2014 MEPS data. All costs are estimated in 2014 dollars. Annual SHS-attributable healthcare costs were estimated for 2000, 2005, and 2010 based on year-specific SHS exposure.

The appropriate sampling weights and the complex sampling design of NHIS were incorporated in the analyses. SEs and 95% CIs were computed. All analyses were conducted in 2016–2018 using SAS, version 9.4 and STATA, version 14.0. A two-tailed p-value <0.05 was considered to be statistically significant.

RESULTS

Of the 16,860 children studied, a total of 2,780 (16.4%) of children were exposed to SHS at home (Table 1). The prevalence of SHS exposure at home for children in 2000, 2005, and 2010 was 25.0%, 12.3%, and 9.1%, respectively. Most of the children were aged 6–14 years, slightly more than half were male, 60.1% were non-Hispanic white, more than half lived in households with middle incomes or greater, and 21.0% had parents with a college degree or more education. On average, 16.6% of studied children were uninsured in ≥1 of the past 12 months. The mean number of months without insurance in the past 12 months for all children was 1.6 months.

Table 2 shows the mean number of hospital nights, ER visits, and doctor visits among all studied children. Children with at least one hospital night had an average of 5.0 hospital nights per year. Similarly, among those with utilization, the mean annual number of ER visits and doctor visits was 1.7 and 1.4 per child, respectively. Bivariate linear regression results show that the mean hospital nights in past 12 months were significantly higher among exposed children (0.3 nights) than among non-exposed children (0.2 nights); similar results hold true for mean ER visits. However, the mean doctor visits in past 2 weeks were not statistically different between exposed children (0.2 visits) and non-exposed children (0.2 visits). The percentage of children having at least one hospital night, at least one ER visit, and at least one

Table 1. Sample Size Distribution by SHS Exposure at Home, Sociodemographic Characteristics and Other Covariates Among Children, 2000, 2005, and 2010 NHIS

Variables	N (%)[a]
Total	16,860 (100.0)
SHS exposure at home	
No	14,080 (83.6)
Yes	2,780 (16.4)
Prevalence of SHS exposure at home by survey year	
2000	N/A (25.0)
2005	N/A (12.3)
2010	N/A (9.1)
Age, years	
3–5	2,836 (15.7)
6–11	9,226 (56.3)
12–14	4,798 (28.0)
Gender	
Male	8,762 (51.2)
Female	8,098 (48.8)
Race and ethnicity	
Non-Hispanic white	8,201 (60.1)
Non-Hispanic African American	2,679 (14.1)
Non-Hispanic Asian	593 (3.5)
Non-Hispanic other	584 (3.6)
Hispanic	4,803 (18.7)
Poverty status (% of federal poverty level)	
Poor (0%–99%)	2,704 (15.8)
Low income (100%–199%)	3,277 (19.0)
Middle income (200%–399%)	4,565 (27.6)
High income (≥400%)	3,720 (22.9)
Unknown	2,594 (14.6)
Parents education	
Less than high school	4,552 (27.0)
High school graduate/GED	4,350 (25.8)
Some college	4,417 (26.2)
College degree or higher	3,541 (21.0)
Year	
2000	7,248 (39.8)
2005	5,280 (31.3)
2010	4,332 (28.9)
Number of months without insurance, past 12 months (mean = 1.61)	
0 months	13,619 (83.4)
1–12 months	3,241 (16.6)

[a]All percentage estimates are weighted.
N/A, not applicable; NHIS, National Health Interview Survey; SHS, secondhand smoke.

doctor visits was 4.4%, 18.8%, and 11.5%, respectively. The percentage of children having at least one utilization was significantly higher among exposed children than unexposed children for hospital nights and for ER visits ($p<0.05$). Among those with positive hospital nights, the mean hospital nights for exposed children (5.3 nights) was not statistically different from the mean hospital nights for unexposed children (5.0 nights). Compared with unexposed children, exposed children had higher mean ER (doctor) visits conditional on having at least one ER (doctor) visits.

The ZIP model results (Table 3) show that after controlling for other covariates, there were no statistical differences between exposed and unexposed children in the likelihood of having hospital nights and in the mean number of hospital nights given hospital utilization. As explained in Methods, because neither of the two components in the ZIP model for hospital nights show a statistically significant coefficient for the SHS exposure variable, the SHS-attributable hospital nights equaled zero. Similarly, because neither of the two components in the ZIP model for doctor visits show a statistically significant coefficient for the SHS exposure variable, the SHS-attributable doctor visits equaled zero. Exposed children were more likely to have ER visits than non-exposed children but did not differ significantly from non-exposed children in the number of ER visits.

SHS exposure at home for children resulted in an excess of 347,156 ER visits in 2000, 124,412 ER visits in 2005, and 101,570 ER visits in 2010 (Table 4). The mean cost per ER visit for children aged 3–14 years was $620 according to the 2014 MEPS data. Therefore, annual SHS-attributable costs for children in 2014 dollars for ER visits was $215.1 million in 2000, $77.1 million in 2005, and $62.9 million in 2010. Because the ZIP model results show no statistically significant association of SHS exposure at home with hospital nights or doctor visit, SHS-attributable costs were assumed to be zero.

DISCUSSION

This study shows that the prevalence of SHS exposure at home for children decreased from 25.0% in 2000 to 9.1% in 2010. These findings are almost identical to those reported in a previous published study in 2016,[9] although the current study focuses on children aged 3–14 years whereas the other study included those aged 0–17 years. This study found that children who were exposed to SHS at home were significantly more likely to have excess ER visits than children who were not exposed. This is consistent with a previous study that found SHS exposure to be positively associated with ER visits, but not with hospitalizations for pulmonary function for children with asthma.[5]

This study's estimates of SHS-attributable healthcare costs indicate that SHS exposure of children at home has

Table 2. Mean Healthcare Utilization and Percentage of Children Having at Least One Utilization by SHS Exposure[a,b]

Variable	N	SHS exposure status			
		Total	Exposed	Non-exposed	*p*-value[c]
Hospital nights[d]					
Mean (among all)	16,860	0.2	0.3	0.2	0.003
Mean (among those with at least one night)	720	5.0	5.3	5.0	0.660
% of those with at least one night (among all)	16,860	4.4	6.6	3.9	<0.0001
ER visits[d]					
Mean (among all)	16,860	0.3	0.4	0.3	<0.0001
Mean (among those with at least one visit)	3,260	1.7	1.8	1.7	0.012
% of those with at least one visit (among all)	16,860	18.8	24.3	17.7	<0.0001
Doctor visits[d]					
Mean (among all)	16,860	0.2	0.2	0.2	0.623
Mean (among those with at least one visit)	2,000	1.4	1.4	1.3	0.033
% of those with at least one visit (among all)	16,860	11.5	11.2	11.5	0.733

[a]All estimates are weighted.
[b]The status of SHS exposure at home for children was based on parent/guardian report.
[c]For the two mean healthcare utilization rates, the bivariate linear regression model was used to test the difference in utilization rates between exposed and unexposed children. The χ^2 test was used to test the difference between exposed and unexposed children in the proportion having positive utilization.
[d]Hospital nights: the number of nights in the hospital in the past 12 months; ER visits: the number of emergency room visits in the past 12 months; Doctor visits: the number of doctor visits in the past 2 weeks.
ER, emergency room; SHS, secondhand smoke.

a substantial economic impact on healthcare costs, totaling $215.1 million in 2000, $77.1 million in 2005, and $62.9 million in 2010 for ER visits alone. For the 3 years analyzed, SHS exposure at home was responsible for 5.2% of all ER visits by children aged 3–14 years.

Smoke-free policies in workplaces and public places have been successfully implemented in past decades.[14] Studies have shown that increased smoke-free restrictions in public places and workplaces are associated with increased voluntary smoke-free home restrictions,[15] which result in a declining prevalence of SHS exposure at home for children. Thus, a large decrease was seen in SHS-attributable costs for children from 2000 to 2010. However, the SHS-attributable cost for children were still high in 2010. Exposure to SHS in the home setting is an important public health issue for children. Evidence has indicated there is no safe level of SHS exposure,[3] so efforts to educate households about the importance of adopting voluntary smoke-free policies are needed. In addition, it is important to implement smoke-free rules in multiunit housing. Research has shown that 34.4% of multiunit housing residents with smoke-free homes were still exposed to SHS because SHS can enter their living units from neighbors' units and shared areas if their neighbors smoke.[16] This study indicates that SHS exposure at home is a risk factor for increased use of ER services. From the higher proportion of exposed children having emergency department visits (24.7%) compared with non-exposed children (17.6%), this setting may be a potential venue for delivering health education to inform parent/caregivers about the harmfulness of SHS for children. Nurses and health educators could take advantage of waiting time in the ER to screen for SHS exposure and provide smoking cessation interventions targeting parents/caregivers whose children were exposed to SHS.

Limitations

This study is subject to some limitations. First, SHS exposure is assessed by parent or guardian report. Thus, the estimates may underestimate the true healthcare costs of SHS exposure at home for children because parents/caregivers may not be willing to disclose their child's SHS exposure, as suggested in a recent study.[17] It is also known that biomarker-measured SHS exposure rates are greater than self-reported SHS exposure rates,[18] but biomarker data were not available for this study. This suggests that the current estimates are likely to underestimate the true SHS-attributable costs. In addition, NHIS is a cross-sectional survey which does not permit the examination of causality between SHS exposure at home and healthcare utilization.

CONCLUSIONS

This study found that SHS exposure-attributable healthcare utilization and costs for children results in a large economic burden relative to all ER visits by children aged 3–14 years. The findings suggest that interventions

Table 3. ZIP Models of Healthcare Utilization and SHS Exposure at Home Among Children Aged 3–14 Years: 2000, 2005, and 2010 NHIS[a,b,c]

Variables	Number of times in hospital overnight, past 12 months		Number of ER visits, past 12 months		Number of doctor visits, past 2 weeks	
	Logit, Coef. (*p*-value)	Poisson, Exp (*p*-value)	Logit, Coef. (*p*-value)	Poisson, Exp (*p*-value)	Logit, Coef. (*p*-value)	Poisson, Exp (*p*-value)
SHS exposure						
No (ref)						
Yes	0.08 (0.48)	0.98 (0.91)	**0.29 (0.01)**	1.07 (0.42)	−0.14 (0.43)	1.07 (0.67)
Age (3–14 years only)						
3,4,. . .14	−0.03 (0.06)	**1.05 (0.03)**	−0.02 (0.08)	**0.98 (0.03)**	−0.01 (0.64)	1.00 (0.79)
Gender						
Male (ref)						
Female	0.09 (0.33)	0.81 (0.21)	**−0.27 (0.00)**	1.05 (0.54)	−0.03 (0.86)	1.09 (0.51)
Race and ethnicity						
NH white (ref)						
NH African American	−0.07 (0.60)	1.36 (0.10)	**−0.21 (0.04)**	**1.42 (0.00)**	−0.24 (0.21)	0.84 (0.30)
NH Asian	**−1.77 (0.00)**	0.94 (0.89)	**−0.92 (0.00)**	1.51 (0.09)	2.20 (0.67)	0.19 (0.18)
NH other	0.07 (0.79)	1.88 (0.07)	0.08 (0.69)	1.17 (0.31)	0.09 (0.78)	1.22 (0.53)
Hispanic	−0.19 (0.17)	1.01 (0.97)	**−0.28 (0.01)**	1.02 (0.84)	−0.13 (0.49)	1.00 (0.98)
Poverty status (% of federal poverty level)						
Poor (0%–99%) (ref)						
Low income (100%–199%)	−0.22 (0.15)	1.06 (0.76)	−0.23 (0.05)	0.83 (0.11)	0.25 (0.38)	0.67 (0.11)
Middle income (200%–399%)	**−0.59 (0.00)**	0.81 (0.32)	**−0.32 (0.01)**	**0.68 (0.00)**	0.21 (0.43)	**0.62 (0.04)**
High income (≥400%)	**−0.83 (0.00)**	1.04 (0.87)	**−0.29 (0.04)**	**0.59 (0.00)**	0.26 (0.41)	0.65 (0.11)
Unknown	−0.23 (0.17)	1.10 (0.70)	**−0.36 (0.01)**	**0.72 (0.01)**	−0.23 (0.42)	0.90 (0.70)
Parent education						
Less than high school (ref)						
High school graduate/GED	**−0.41 (0.01)**	**0.52 (0.00)**	0.11 (0.48)	0.85 (0.26)	−0.38 (0.22)	1.23 (0.48)
Some college	−0.31 (0.05)	**0.55 (0.00)**	−0.07 (0.63)	0.80 (0.12)	0.06 (0.84)	0.97 (0.92)
College degree or higher	**−0.63 (0.00)**	0.72 (0.37)	0.11 (0.58)	0.76 (0.11)	−0.37 (0.25)	1.02 (0.95)
Year						
2000 (ref)						
2005	**−1.74 (0.00)**	0.64 (0.16)	0.23 (0.09)	**0.73 (0.01)**	−0.42 (0.17)	0.79 (0.41)
2010	**−1.88 (0.00)**	0.77 (0.30)	0.19 (0.17)	0.81 (0.09)	−0.31 (0.31)	0.78 (0.33)
Number of months no insurance						
0–12 months	**−0.04 (0.00)**	0.98 (0.21)	0.00 (0.92)	0.99 (0.25)	−0.04 (0.09)	0.96 (0.06)

[a]All estimates are weighted.
[b]Bold results indicate statistical significane at the $p<0.05$ level.
[c]The status of SHS exposure at home for children was based on parent/guardian report.
Coef., coefficient; ER, emergency room; Exp, exponentiated coefficients; GED, general educational development; NH, non-Hispanic; NHIS, National Health Interview Survey; SHS, secondhand smoke; ZIP, Zero-inflated Poisson.

Table 4. Annual Healthcare Utilization and Cost Attributable to SHS Exposure at Home Among Children Aged 3–14 Years (2014 Dollars)[a]

	SHS-attributable healthcare utilization ($ thousand)			SHS-attributable cost ($ million)		
Variable	2000	2005	2010	2000	2005	2010
ER visits/Total costs	347.2	124.4	101.6	215.1	77.1	62.9

[a]The status of SHS exposure at home for children was based on parent/guardian report.
ER, emergency room; SHS, secondhand smoke.

to reduce SHS exposure at home for children are needed to reduce the economic burden attributable to SHS.

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