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**Childhood secondhand smoke exposure and ADHD-attributable costs
to the health and education system**

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ABSTRACT

BACKGROUND: Children exposed to secondhand smoke (SHS) have higher rates of behavioral and cognitive effects, including attention deficit hyperactivity disorder (ADHD), but the costs to the healthcare and education systems have not been estimated. We estimate these costs for school-aged children aged 5-15.

METHODS: The relative risk (RR) of ADHD from SHS exposure was obtained from our previous work. SHS exposure was measured using two alternative approaches – reported exposure and serum cotinine measured exposure. RRs and SHS exposure were used to determine the number of children with SHS-attributable ADHD, and mean costs of ADHD-related healthcare and education services were applied to obtain SHS-attributable healthcare and education costs.

RESULTS: Annual healthcare costs of SHS-attributable ADHD ranged from \$644 million (using reported SHS exposure) to \$2.05 billion (using cotinine-measured exposure). SHS-attributable costs to the education system ranged from \$2.90 billion to \$9.23 billion.

CONCLUSIONS: The costs of SHS-attributable ADHD to the education system may total more than 4 times the costs for healthcare. The huge economic impact of SHS exposure on the education system has not been previously documented, and suggests that reducing childhood exposure to tobacco smoke will release substantial funds that could be used for general education of all children.

Keywords: child & adolescent health, public health, mental health, smoking & tobacco

INTRODUCTION

Children exposed to secondhand smoke (SHS) experience a number of negative health effects, including asthma, respiratory infections, and ear infection. In addition, a number of studies have reported behavioral and cognitive effects, including poor performance in school, conduct problems, and externalizing behaviors.³⁻⁶ While it has long been accepted that maternal smoking while pregnant is associated with childhood attention deficit hyperactivity disorder (ADHD),⁷ increasing evidence suggests that childhood SHS exposure is also strongly associated with ADHD, independent of other risk factors. The mechanisms underlying this relationship are not yet fully understood, but the findings have been reported by researchers using a variety of approaches. Given that ADHD is one of the most prevalent mental disorders in children and can persist into adulthood, it is important to understand the economic implications that SHS exposure has for ADHD. We estimate here the economic impact of SHS-attributable ADHD for the healthcare and education systems.

METHODS

We previously analyzed data on over 6000 nonsmoking children aged 4-15 from the 1999-2004 National Health and Nutrition Examination Survey (NHANES) to determine the relationship between SHS exposure and ADHD; details of the analyses are contained elsewhere.⁸ Analyses accounted for the complex survey design by using sampling weights to adjust for the probability of sample selection, nonresponse, and sample noncoverage in this complex survey design.⁸ The NHANES is nationally representative of noninstitutionalized persons in the US, and contains both a survey and an examination component. Questions about ADHD are only asked for children aged 4 and older; an upper age limit of 15 was used because the question about maternal smoking while pregnant was asked of children up to age 15 and this was an important covariate in our analyses.

We defined ADHD as parent or guardian responding positively to either of the following two questions: “Has a doctor of health professional ever told you that your child had attention deficit disorder?” or “In the past 30 days, has your child used or taken medication for which a prescription is needed” with the parent indicating that one of the medications used was a stimulant of a specific type used to treat ADHD.⁸

Childhood Exposure to SHS

Childhood exposure to SHS was measured using two alternative approaches: parent/guardian reporting of someone living in the household smoking inside the home, and serum cotinine, a metabolite of nicotine whose presence indicates recent exposure to nicotine and is used as a biomarker for exposure to tobacco smoke.⁸ Serum cotinine was measured through a blood sample collected during the examination component of the NHANES.⁸ A detectable serum cotinine level of $\geq .05$ ng/mL was used to indicate SHS exposure. This low level has nonetheless been reported to be associated with negative health impacts. Both measures of SHS exposure were used, because while many studies rely solely on a reported measure of SHS exposure, it has been shown that this type of measure greatly underestimates the number of children exposed.¹¹

The Relative Risk of ADHD from SHS Exposure

The relative risks of ADHD from SHS exposure were estimated using multiple logistic regression models to estimate adjusted odds ratios controlling for sociodemographic factors (gender, age, race/ethnicity, parental education, and poverty status), preschool attendance, health insurance coverage (yes/no), whether the mother smoked while pregnant (self report of having smoked at any time during pregnancy), and exposure to other environmental agents such as lead

(blood lead concentration categorized into quintiles) and organophosphate pesticides (urinary concentration of dimethyl alkylphosphates).

Total Healthcare Costs of ADHD

For purposes of comparisons with education costs of school-aged children, we estimated the total healthcare costs of ADHD in children aged 5-15. We determined the mean total healthcare costs of ADHD from the 2008-2010 Medical Expenditures Panel Survey, which we updated to 2012 dollars using the medical care component of the consumer price index.

SHS-Attributable Healthcare Costs of ADHD

The proportion of ADHD healthcare costs attributed to SHS exposure was calculated using the standard epidemiological equation for attributable fractions,¹² based on the relative risk of ADHD from SHS exposure and the rate of exposure to SHS. The attributable fractions were multiplied by the total ADHD healthcare costs to estimate that the healthcare costs of ADHD that can be attributed to SHS.

SHS-Attributable ADHD Education Costs

A recent study reported that the annual cost of ADHD to the education system for school-aged children was \$8,061 per ADHD child (inflated to 2012 dollars using the education component of the Consumer Price Index).¹³ This cost included special education, grade retention, and disciplinary actions. This was multiplied by the number of school-aged children (aged 5-15) in the US, and the attributable fractions described above to determine the SHS-attributable cost of ADHD to the education system.

RESULTS

Childhood Exposure to SHS

Many children are exposed to secondhand smoke. Using parent/guardian reporting of someone living in the household smoking inside the home, we found that 22.3% (95% Confidence Interval (CI): 21.1-26.0) of children were exposed.⁸ Using serum cotinine, we found that 58.3% (95% CI: 53.8-62.9) of children were exposed to SHS.⁸

The Relative Risk of ADHD from SHS Exposure

The relative risk of ADHD from SHS exposure using reported exposure was 1.5 (95% CI: 1.1-2.0; $p=.007$) and the relative risk of ADHD using serum cotinine was 1.8 (95% CI: 1.3-2.5; $p=.001$).⁸ This indicates that a child exposed to SHS is 1.5 - 1.8 times as likely to have ADHD as a child who is not exposed, even after controlling for other risk factors.

Total Healthcare Costs of ADHD

The mean annual cost of treating a child with ADHD was \$1789, primarily reflecting medications and office-based provider visits. Given that the Census reports 45 million children in the U.S. aged 5-15 in 2012¹⁴ and our finding that 8.0% of children have ADHD,⁸ we calculate that there are approximately 3.6 million children with ADHD in this age group. Thus, the total annual healthcare costs for ADHD would equal \$6.44 billion.

SHS-Attributable Healthcare Costs of ADHD

The SHS-attributable fraction of ADHD costs is 10.0% using reported SHS exposure, and 31.8% using cotinine-measured SHS exposure. Multiplying the attributable fractions by the total ADHD healthcare costs, we estimate that the healthcare costs of ADHD attributed to SHS exposure range from \$644 million (reported exposure) to \$2.05 billion (cotinine-measured exposure), as shown in Table 1.

Cost of SHS-Attributable ADHD to the Education System

Multiplying the per student education cost of ADHD by 3.6 million children with ADHD and the SHS-attributable fraction of ADHD cost yields a cost to the education system of \$2.90 billion (reported exposure) to \$9.23 billion (cotinine-measured exposure) attributable to SHS exposure (see Table 1).

DISCUSSION

Childhood exposure to SHS is associated with ADHD, and results in substantial costs to both the healthcare system and the education system that may total nearly \$11.3 billion a year. It is important to educate parents that their children's exposure to SHS may be greater than they realize. The school is an important venue where education of parents about SHS can take place. When a reliable point-of-care screen for cotinine becomes available, routine screening of children should be considered. In the meantime, efforts to reduce smoking prevalence and to protect children from SHS exposure must continue. This issue is important not only in the US but also internationally, where it has been reported that as many as half of all children are exposed to SHS at home¹⁵ and where ADHD rates are thought to be as high as they are in the US.¹⁶

Our findings suggest a number of areas for future research. First, more research is needed to address the education-related costs of SHS-attributable conditions. We estimate costs for only one SHS-related condition that impacts schools. Other SHS-related conditions, including asthma, middle ear infections, and respiratory symptoms and infections, are likely to lead to school absenteeism¹⁷ and could also lead to poor academic performance and even grade retention by affected children. Absences can lead to loss of funding for schools which receive funding based on daily census. In addition, absences that lead to missed school days may impact family members who must miss work or other activities to care for children who are unable to

attend school. For example, a recent study found that caregivers' time tending children aged 6-11 years with SHS-attributable school loss days amounted to \$227 million per year.¹⁷ All these potential costs should be explored in greater detail. Second, the impact of SHS-attributable ADHD may impact some populations more than others. For example, costs may be greater for minorities and low socioeconomic groups who have relatively high rates of SHS exposure. Similarly, SHS exposure differs by state and locality, and thus the impact on the educational system is likely to be greater in some areas than in others. More research on this issue would be useful for developing targeted interventions. Third, while it has been shown that children exposed to SHS have greater rates of ADHD, the impact of reducing SHS exposure on ADHD has not been addressed. Research on this issue would help inform the development of policies and interventions related to childhood SHS exposure.

IMPLICATIONS FOR SCHOOL HEALTH

Our findings could be useful in intervention and education programs for families of children with ADHD as well as for educators. Parents should be educated about the potential impact of SHS exposure on their children's health and educational prospects and urged to minimize this exposure. Educators should also be informed about the role that SHS exposure may play for their students, and urged to share this information with families when appropriate. Any anti-smoking education programs implemented by schools should also incorporate information about the impact of SHS exposure on children's cognition and behavior and also the large cost to the education system.

The relatively high costs to the education system resulting from SHS exposure have not been previously reported. Our findings suggest that the cost to the education system for SHS-attributable ADHD may be more than 4 times as great as the cost to the healthcare system. This

suggests that tobacco control programs may have a much broader impact than is usually estimated based solely on healthcare costs.

Policies that reduce childhood SHS exposure will reduce the high costs that ADHD imposes on the education system and release substantial funds that could be used for general education of all children.

HUMAN SUBJECTS' APPROVAL

This research was certified as exempt by the University of California, San Francisco Committee on Human Research.

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Table 1. SHS-Attributable Costs of ADHD to the Healthcare and Education Systems for Children Aged 5-15: U.S., 2012

	Healthcare costs	Education costs	Total costs
	(\$ millions)		
SHS exposure measure			
Reported	644	,902	,546
Cotinine Measured	2,050	9,228	11,278