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Secondhand Smoke Exposure and Subsequent Academic Performance Among U.S. Youth

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Abstract

Introduction: Previous research shows the associations between secondhand smoke exposure and health consequences among youth, but less is known about its effect on academic performance. This study examines a dose–response relationship between secondhand smoke exposure and subsequent academic performance among U.S. youth.

Methods: Data were from a nationally representative sample of youth non-tobacco users (aged 12–16 years) in Wave 2 (2014–2015) who completed Wave 3 (2015–2016) of the Population Assessment of Tobacco and Health Study (n=9,020). Past 7–day number of hours exposed to secondhand smoke at Wave 2 and academic performance at Wave 3 (1=Mostly A's to 9=Mostly F's) were assessed. Weighted multivariable linear regression models were used to examine the association between hours of self-reported secondhand smoke exposure at Wave 2 and academic performance at Wave 3 (1=Mostly F's, 9=Mostly A's), adjusting for covariates including sociodemographics, prior academic performance, internalizing and externalizing problems, and substance use problems. Analyses were conducted in 2019.

Results: More than 30% of U.S. youth non-tobacco users were exposed to secondhand smoke in the past 7 days. Compared with unexposed youth at Wave 2, those who were exposed for 1–9 hours had poorer academic performance at Wave 3 (adjusted regression coefficient= −0.11, 95% CI= −0.18, −0.04), and those who were exposed for ≥10 hours at Wave 2 had even poorer academic performance (adjusted regression coefficient = −0.31, 95% CI= −0.45, −0.18).

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Conclusions: A dose–response relationship was observed between secondhand smoke exposure and academic performance among U.S. youth. Reducing youth secondhand smoke exposure may promote academic performance and subsequent educational attainment.

INTRODUCTION

Although secondhand smoke exposure has decreased over time owing to momentous progress in tobacco control, nearly one in three U.S. adolescents remains regularly exposed to this known health hazard.[1] To date, disparities in secondhand smoke exposure persist among non-smoking adolescents nationwide. Adolescents who are non-Hispanic black, of lower SES, or have parents with lower educational attainment have disproportionately high prevalence rates of secondhand smoke exposure.[1] These rates are of concern as even minimal exposure to secondhand smoke is unsafe.[2] Commonly reported secondhand smoke exposure-related health effects among adolescents include, but are not limited to, respiratory symptoms and infections, ear problems and infections, asthma, and lower overall health and physical health status.[3–5] Longitudinal research also indicates that child secondhand smoke exposure is associated with internalizing and externalizing behaviors over time.[6] Prior research has linked secondhand smoke exposure with attention deficit hyperactivity disorder, which is characterized by inattention and hyperactive–impulsive behavior.[7] There is irrefutable evidence that continued exposure to secondhand smoke across one's lifespan has detrimental effects. The overall economic toll that secondhand smoke exposure has on the U.S. is substantial with an estimated $6.6 billion in lost productivity and 42,000 related deaths each year.[8]

Previous research applying the social epidemiological framework to investigate academic failure has identified risk factors for poor academic performance, which include being racial/ethnic minorities and of low SES, as well as having emotional distress, substance use history, and previous trouble with homework.[9,10] However, limited evidence exists on the relationship between secondhand smoke exposure and cognitive deficits, including school retention, intelligence test scores, and reading and language scores.[4,11] A previous cross-sectional study conducted in Hong Kong found that secondhand smoke exposure was associated with poor academic performance among non-smoking adolescents.[12] Two other studies showed that secondhand smoke exposure during adolescence was associated with early grade retention and lower standardized test scores.[13] Although longitudinal studies have examined the potential impact of childhood secondhand smoke exposure on intelligence during adolescence, no studies to date have examined the longitudinal association between secondhand smoke exposure and subsequent academic performance during this critical developmental period. Academic performance is one of the requirements to achieve higher educational attainment, which has been linked to better health.[14] Thus, more research is needed to identify the relationship between secondhand smoke exposure and academic performance among non–tobacco using adolescents.

The study examines a dose–response relationship between secondhand smoke exposure and subsequent academic performance among a national sample of non–tobacco using adolescents. The hypothesis is that as the amount of secondhand smoke exposure increases, academic performance decreases over time, after accounting for sociodemographics (e.g.,

race/ethnicity, annual household income), internalizing problems, externalizing problems, substance use problems, and prior academic performance as measured by the Population Assessment of Tobacco and Health (PATH) study.

METHODS

Study Sample

This study used Wave 2 (2014–2015) and Wave 3 (2015–2016) youth surveys (public files) of the PATH study, which includes a nationally representative, longitudinal cohort of civilian, non-institutionalized youth and adults in the U.S.[15] The PATH study used audio computer-assisted self-administered interviews in English and Spanish to collect information on respondents' health status and tobacco use behavior.[15] The PATH youth survey was also accompanied by a short questionnaire completed by youth respondents' parents or legal guardians. The numbers of youth respondents who completed Waves 1, 2, and 3 surveys were 13,651, 12,172 and 11,814, respectively. The weighted interview response rates for Waves 2 and 3 youth respondents who completed Wave 1 survey were 87.3% and 83.3%, respectively.[16] Of these youth respondents, 9,542 completed both Waves 2 and 3 surveys. Youth respondents who reported using any type of tobacco products (e.g., cigarettes, e-cigarettes, cigars, hookah, smokeless tobacco, tobacco pipes) within the past month were further excluded from the analytic sample (n=522). The study included those who aged up to 12 years at Wave 2 but excluded those who were aged ≥18 years at Wave 3 from the analysis. Therefore, the youth included for this analysis were aged 12–16 at Wave 2, resulting in 9,020 youth non–tobacco users at Wave 2 followed into Wave 3.

Measures

At Wave 3, parents of the youth respondents were asked: *How would you describe how [child's first name] has performed at school in the past 12 months? Would you say [child's first name]'s grades are…* The response options ranged from 1=*Mostly F's* to 9=*Mostly A's* and also included 10=*School is ungraded*. Based on this variable, a new continuous variable (range=1–9, mean=7.41, SE=0.02) for academic performance was generated with higher numbers indicating better grades and lower numbers indicating worse grades (e.g., 1=*Mostly F's*, 9=*Mostly A's*). The respondents whose parents reported *School is ungraded* (n=47) were excluded from the analysis.

At Wave 2, youth respondents were asked: *During the past seven days, about how many hours were you around others who were smoking? Include time in your home, in a car, at school, or outdoors*. The respondents filled out the number of hours that they were exposed to secondhand smoke. For this analysis, the number of hours was further categorized into three levels (0 hours as no exposure, 1–9 hours, and ≥10 hours).

The following sociodemographic characteristics at Wave 2 were used as covariates for academic performance: age, sex, race/ethnicity, annual household income, and the highest educational attainment of parents (Table 1). Psychosocial covariates used for the analysis were self-reported past-year internalizing problems (e.g., depression, anxiety, distress, and sleeping), externalizing problems (e.g., having a hard time paying attention, having a hard

time listening to directions, and being bullied or threatening others), and substance use problems (e.g., used alcohol or other drugs, spent a lot of time getting alcohol and other drugs, withdrawal problems).[17] Internalizing, externalizing, and substance use problems were measured by the Global Appraisal of Individual Needs Short Screener.[18] These questions demonstrated moderate to high validity and reliability among the youth population.[19] Past-year academic performance reported at Wave 2 was included as a covariate, measured in the same way as academic performance at Wave 3. The authors did not control for living with a tobacco user because of its strong association with secondhand smoke exposure (chi-square statistics=1415.69, $p<0.0001$). The authors did not control for Wave 3 tobacco use because a previous study suggested that exposure to secondhand smoke was associated with smoking initiation among youth.[20]

Statistical Analysis

The following statistical analyses were conducted using Stata, version 14.0 to achieve the research aims. First, the prevalence of Wave 2 secondhand smoke exposure based on respondents' sociodemographic and psychosocial characteristics was estimated. Second, separate multivariable linear regression models were used to assess the associations between Wave 2 secondhand smoke exposure and Wave 3 academic performance, controlling for Wave 2 covariates. Data analysis accounted for the Wave 3 longitudinal weights for calculating proportions with 95% CIs, using the balanced repeated replications method with Fay's adjustment of 0.30.[16] Imputed sociodemographic covariates from the PATH public file were used, and the "undetermined" category was used for variables with missing values (including "refused to answer") >5% of the sample. The observations with missing values <5% of individual variables were excluded from the regression procedures (i.e., listwise deletion of missing data).[21] In a sensitivity analysis, the authors further adjusted for peer smoking. This research only involved the use of de-identified data, which is not considered human subjects research and requires no IRB review or approval per NIH policy and 45 CFR 46. Analyses were conducted in 2019.

RESULTS

Overall, among U.S. youth non-tobacco users, 62.2% were aged 12–14 years, and 52.9% were non-Hispanic white; 64.2% reported past-year internalizing problems, and 72.6% reported past-year externalizing problems (Table 1). About two in three U.S. youth non-tobacco users reported no exposure to secondhand smoke in the past 7 days, whereas more than one in four reported up to 9 hours of exposure, and about one in 20 reported ≥10 hours of exposure to secondhand smoke. On average, the academic performance of U.S. youth non-tobacco-users was between 7=*mostly B's* and 8=*A's and B's*.

In the multivariable linear regression model, a dose–response relationship was observed between hours exposed to secondhand smoke in the past 7 days at Wave 2 and academic performance at Wave 3, after adjusting for Wave 2 sociodemographic background, past-year externalizing and internalizing problems, past-year substance use problems, and past-year academic performance (Table 2). Compared with U.S. non–secondhand smoke exposed youth, those who reported 1–9 hours of exposure showed lower academic performance

(adjusted regression coefficient [ARC]= −0.11, 95% CI= −0.18, −0.04), and those who reported ≥10 hours of exposure showed an even lower academic performance (ARC= −0.31, 95% CI= −0.45, −0.18). Being female (compared with male), living in household with annual income ≥$50,000 (compared with <$50,000), having college-educated parents (compared with high school or less), and having better academic performance (compared with lower performance) at Wave 2 were associated with having higher academic performance at Wave 3. By contrast, being non-Hispanic black (compared with non-Hispanic white) and having substance use problems in the past year (compared with not having substance use problems in the past year) at Wave 2 were associated with lower academic performance at Wave 3 ($p<0.05$). In a sensitivity analysis further adjusting for peer smoking, the association between Wave 2 secondhand smoke and Wave 3 academic performance remained significant (0–9 hours of exposure: ARC= −0.09, 95% CI= −0.16, −0.02; ≥10 hours of exposure: ARC= −0.29, 95% CI= −0.43, −0.16).

DISCUSSION

Using data from a nationally representative longitudinal cohort of adolescent non-tobacco users, the current analysis found that exposure to secondhand smoke exhibited a statistically significant dose–response relationship with subsequent academic performance. Previous studies have found that exposure to secondhand smoke was associated with lower cognitive abilities in children and adolescents,[11,13] and another study in Hong Kong showed an association between exposure to secondhand smoke and lower academic performance in youth.[12] Findings from the current analysis support and corroborate with those from previous studies, and further extend the body of literature from cross-sectional to longitudinal associations, potentially improving causal inference. Furthermore, this study adds to the limited understanding of the association between adolescent secondhand smoke exposure and academic performance. Previous research demonstrated the detrimental health impact of secondhand smoke exposure among adolescents, for example, respiratory symptoms and infections, ear problems and infections, and asthma.[3–5] These secondhand smoke exposure–related conditions can lead to school absenteeism,[22–25] which may explain how exposure to secondhand smoke impacts adolescents' academic performance. An alternative explanation could be that exposure to secondhand smoke may be a marker of deviant behaviors or association with deviant peers. The PATH study does not ask questions about deviant peers. However, as the current analysis adjusted for substance use problems, internalizing and externalizing problems, and academic performance in Wave 2, these alternative explanations are unlikely to account for the observed associations. Finding from the current analysis may also partly explain a previously observed association between worse adolescent health and lower likelihood of high school graduation and post-secondary education enrollment.[26] Educational attainment has been considered as one of the fundamental causes of a variety of health outcomes.[27] Therefore, it is possible that adolescent secondhand smoke exposure, through its influence on adolescent health and academic performance, contributes partly to poor health outcomes later in life. Thus, efforts to reduce adolescents' exposure to secondhand smoke may improve their academic performance, which may in turn further promote higher educational attainment and better health outcomes during adulthood.

Although the PATH study did not assess the places where youth are exposed to secondhand smoke, data from the 2013 National Youth Tobacco Survey showed that among U.S. middle school and high school students, 39.9% reported exposure to secondhand smoke for ≥1 day in the past 7 days at indoor/outdoor public area, 39.7% at work, 25.0% at vehicle, 24.9% at school, and 23.9% at home.[28] Moreover, compared with non-Hispanic white students, non-Hispanic black students were more likely to report exposure to secondhand smoke at work and at indoor/outdoor public areas.[28] A previous report showed among youth who were not exposed to secondhand smoke at home, those living in counties with comprehensive smoke-free air laws were less likely to be exposed to secondhand smoke compared to those living in counties without such laws.[29] Additionally, complete smoke-free home and vehicle rules and complete compliance with smoke-free school rules are associated with lower youth exposure to secondhand smoke at home, work, and public areas.[28] Although 59% of the U.S. population lives in areas with a strong smoke-free workplace law,[30] non-Hispanic blacks were less likely than non-Hispanic whites to be covered by a smoke-free law at restaurants and bars.[31] Furthermore, as the prevalence of smoke-free homes increased over time, non-Hispanic black households with smokers and children are still less likely than non-Hispanic white households to adopt a smoke-free home rule or to live in multiunit housing with a smoke-free policy.[32,33]

Therefore, to protect all youth from secondhand smoke exposure, especially its racial/ethnic disparities, it is important to adopt comprehensive smoke-free policies. The WHO Framework Convention on Tobacco Control Article 8 highlights the importance of protection from exposure to tobacco smoke through adopting and implementing policies for "indoor workplaces, public transport, indoor public places and, as appropriate, other public places."[34] An increasing number of cities across the globe have participated in the WHO's smoke-free city initiatives.[35] Efforts to promote adoption and implementation of comprehensive smoke-free policies are especially needed in racial/ethnic minority communities. In addition to efforts at the community level, other multilevel efforts are needed to protect youth from secondhand smoke. For example, one potential intervention to reduce secondhand smoke disparities would be to promote the adoption and enforcement of existing smoke-free multiunit housing policies, particularly in public housing. In 2016, the U.S. Department of Housing and Urban Development issued a final rule requiring all public housing premises to be smoke free.[36] By mid-2017, a total of 527 Public Housing Authorities in the U.S. enacted policies prohibiting smoking.[37] The effect of these policies on residents' exposure to secondhand smoke is yet to be evaluated. Another intervention would be for healthcare providers to connect parents, especially those from racial/ethnic minority populations, with resources to assist with the adoption of smoke-free home rules and smoking cessation.[38]

Future research is warranted to understand the structural factors at multiple levels (e.g., family, multiunit housing complex, city/county) that hinder the adoption of these policies. These factors may include physical infrastructure of the building complex, perceived neighborhood safety, perceived rationale for these policies (i.e., whether smokers think the policies are mean to protect people from secondhand smoke versus simply penalizing smokers), coverage of other substance use in the policies (e.g., electronic cigarettes, marijuana), potential enforcement challenges, availability of cessation resources, and

perceived effectiveness of these policies in reducing secondhand smoke exposure.[36,39] Some of these factors may be particularly impactful in racial/ethnic minority communities as previously reported.[39] Moreover, further research is needed to evaluate how modifying these factors may lead to more equitable adoption and implementation of comprehensive smoke-free policies.

The strengths of this study include using a nationally representative sample, longitudinal study design, and exclusion of all current tobacco use instead of just cigarettes at baseline.

Limitations

However, these findings should be interpreted with the following limitations. First, secondhand smoke exposure was measured by self-report, and therefore may be subject to errors. However, a previous study found a high correct classification rate (>85%) for secondhand smoke exposure based on serum cotinine.[40] Second, academic performance was also measured by self-report through parents and may be subject to misreport. Third, some known risk factors of poor academic performance were not measured in the PATH study and therefore could not be accounted for in the regression models. These included school contextual factors (e.g., student–teacher bonding), neighborhood factors, and educational policy factors. However, it is unclear how these factors are related to exposure to secondhand smoke, and how much of their impact on academic performance is already accounted for by adjusting for Wave 2 academic performance.

CONCLUSIONS

The current analysis observed a prospective dose–response relationship between secondhand smoke exposure and subsequent academic performance among U.S. youth non-tobacco users. These findings are part of the initial step in demonstrating the association between secondhand smoke exposure and academic performance. Future studies are needed to confirm these findings, as well as to elucidate the potential mechanisms underlying this association. If confirmed, these findings also suggest that efforts to reduce secondhand smoke exposure among youth may lead to an improvement in academic performance, which in turn could promote higher educational attainment and better health outcomes later in life.

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KC conceptualized and designed the study, contributed to the draft of the initial manuscript, and reviewed and revised the manuscript. JCC-S conducted data analysis, contributed to the draft of the initial manuscript, and reviewed and revised the manuscript. ALM contributed to the draft of the initial manuscript and reviewed and revised the manuscript. CMcG reviewed and revised the manuscript for important intellectual content and cultural context. VY introduced the research question, and reviewed and revised the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Table 1.

Weighted Sample Characteristics, PATH Study (Waves 2 and 3 Youth Interviews) 2014–2016

Sample characteristics	Overall (N=9,020) Weighted % (95% CI)
Age, %	
12–14 years	62.2 (61.7, 62.7)
15–16 years	37.8 (37.3, 38.4)
Sex, %	
Female	48.7 (48.3, 49.1)
Male	51.3 (50.9, 51.7)
Race and ethnicity, %	
Non-Hispanic white	52.9 (52.4, 53.4)
Non-Hispanic black	13.8 (13.4, 14.1)
Hispanic	23.5 (23.2, 23.9)
Non-Hispanic other	9.8 (9.5, 10.2)
Annual household income, %	
<$50,000	41.2 (39.8, 43.2)
≥$50,000	46.8 (45.2, 48.4)
Undetermined	11.7 (10.8, 12.7)
Parental education attainment, %	
High school or less	31.5 (29.9, 33.2)
Some college	28.5 (27.0, 30.1)
College or more	32.5 (30.4, 34.7)
Undetermined	7.4 (6.8, 8.1)
Past-year internalizing problems at Wave 2, %	
Yes	64.2 (63.0, 65.4)
No	35.8 (34.6, 37.0)
Past-year externalizing problems at Wave 2, %	
Yes	72.6 (71.5, 73.6)
No	27.5 (26.4, 28.6)
Past-year substance use problems at Wave 2, %	
Yes	8.1 (8.3, 8.9)
No	92.0 (91.1, 92.7)
Hours of secondhand smoke exposure in the past 7 days at Wave 2	
No exposure	68.1 (66.4, 69.7)
1–9 hours	26.6 (25.2, 28.0)
≥10 hours	5.3 (4.8, 5.9)
Academic performance at Wave 2[1], weighted mean (95% CI)	7.4 (7.4, 7.5)
Academic performance at Wave 3[1], weighted mean (95% CI)	7.4 (7.4, 7.5)

Notes: Academic performance variable is an ordinal variable with the range of 1=Mostly F's, 2=D's and F's, 3=Mostly D's, 4=C's and D's, 5=Mostly C's, 6=B's and C's, 7=Mostly B's, 8=A's and B's, and 9=Mostly A's.

PATH, Population Assessment of Tobacco and Health.

Table 2.

Weighted Associations Between Wave 2 Characteristics and Wave 3 Academic Performance

	Academic performance at Wave 3 (N=8,557)
Wave 2 characteristics	**Beta (95% CI)**
Hours of secondhand smoke exposure in the past 7 days	
No exposure	ref
1–9 hours	**−0.11 (−0.18, −0.04)**
≥10 hours	**−0.31 (−0.45, −0.18)**
Age	
12–14 years	ref
15–16 years	0.02 (−0.03, 0.07)
Sex	
Male	ref
Female	**0.29 (0.24, 0.34)**
Race and ethnicity	
Non-Hispanic white	ref
Non-Hispanic black	**−0.22 (−0.32, −0.14)**
Hispanic	−0.06 (−0.13, 0.01)
Non-Hispanic other	0.03 (−0.05, 0.17)
Annual household income	
<$50,000	ref
≥$50,000	**0.15 (0.07, 0.22)**
Undetermined	0.04 (−0.10, 0.18)
Parental education attainment	
High school or less	ref
Some college	−0.01 (−0.09, 0.07)
College or more	**0.21 (0.13, 0.29)**
Undetermined	0.09 (−0.07, 0.25)
Past-year internalizing problems	
Yes	0.01 (−0.06, 0.08)
No	ref
Past-year externalizing problems	
Yes	0.07 (−0.01, 0.14)
No	ref
Past-year substance use problems	
Yes	**−0.21 (−0.33, −0.08)**
No	ref
Academic performance	**0.62 (0.60, 0.66)**

Notes: Academic performance variable is an ordinal variable with the range of 1=Mostly F's, 2=D's and F's, 3=Mostly D's, 4=C's and D's, 5=Mostly C's, 6=B's and C's, 7=Mostly B's, 8=A's and B's, and 9=Mostly A's. Boldface indicates statistical significance ($p<0.05$).