Exposure to Secondhand Smoke and Academic Performance in Non-Smoking Adolescents

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Objective To study the association between exposure to secondhand smoke (SHS) and academic performance in non-smoking adolescents.

Study design A questionnaire survey of 23 052 non-smoking students aged 11 to 20 years was conducted. Information on academic performance, number of days of SHS exposure per week at home and outside the home, number of smokers at home and their relationship with the student, and sociodemographic characteristics was recorded.

Results Students exposed to SHS at home 1 to 4 and 5 to 7 days per week were 14% (95% confidence interval, 5%-25%) and 28% (15%-41%) more likely, respectively, to report poor academic performance compared with students who were not exposed to SHS. Living with one, two, and ≥3 smokers, compared with no smoker, was also associated with 10% (0.1%-20%), 43% (23%-65%) and 87% (54%-127%), respectively, higher odds of poor academic performance (*P* for trend <.001). The greatest excess risks were observed with SHS exposure from co-residing non-relatives, followed by siblings, visitors, co-residing grandparents and relatives, and parents.

Conclusion SHS exposure is associated linearly with poor academic performance in non-smoking adolescents, and the effect of SHS exposure at home is stronger from smokers other than the parents. *(J Pediatr 2010;157:1012-7)*.

Prenatal tobacco exposure and postnatal secondhand smoke exposure (SHS) were shown to be associated with poor cognition in children,[1] but the evidence is still insufficient to infer causality.[2] A recent review has suggested that adolescent cognition was not associated with prenatal or early life tobacco exposure,[3] but was associated with the SHS exposure during adolescence.[4] It has been suggested that carbon monoxide in SHS can bind with hemoglobin to form carboxyhemoglobin in blood, depleting oxygen supply to the brain, and adversely affect mental performance.[5]

A PubMed search from January 1960 to April 2009 using the criteria "passive or second-hand or involuntary or environmental" AND "smok$ or tobacco$ or cigarette$" AND "cogniti$ or recogniti$ or neuro$ or memor$ or intelligen$ or intellect$ or IQ or learning or academic$" AND "adolescent$ or teenage$ or youth$ or juvenescen$" ($ indicates one or more characters) yielded only 3 relevant reports on exposure to SHS and cognition in adolescents.[4-6] However, these studies invariably focused on SHS exposure from parents, neglecting other potential sources.[4,5]

Educational success is of utmost importance to Chinese families. Therefore, any adverse effect of SHS exposure on adolescent academic performance, especially when supported by local data, will likely give new impetus for Chinese families to establish smoke-free homes. This is particularly important in places like Hong Kong, where homes are typically small and the effect of indoor smoking is magnified. We investigated the association between SHS exposure, particularly at home, and academic performance in Hong Kong Chinese non-smoking adolescents and compared the effects of SHS exposure from parents and other sources.

Methods

From February 2003 to April 2004, a youth smoking survey with a self-administered questionnaire was conducted in Hong Kong with a high response rate (98%) from students in 85 mainstream secondary schools (non-international schools), which were randomly selected with a probability proportional to school enrollment size pursuant to the requirement of the Global Youth Tobacco Survey.[7] Classes from Form 1 to 5 (grades 7-12 in the United States) of the participating schools (total = 1012 classes) were surveyed. The institutional review board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster granted ethical approval for the study.

The students reported their SHS exposure on the basis of two standard questions used in the Global Youth Tobacco Survey:[7] "How many days in the past 7 days did someone smoke near you when you were at home?" and "How many

CI	Confidence interval
ER	Excessive risk
SHS	Secondhand smoke

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days in the past 7 days did someone smoke near you when you were outside home?" The total number of co-residing smokers and their relationships with the student were also reported. Information about basic demographic characteristics, socioeconomic status, respiratory health, academic aspirations, smoking, and other lifestyle factors of the students was also collected. Academic performance was assessed with the item "your academic performance is," with options of very poor, poor, average, good, and very good, which were analyzed as poor (very poor and poor) versus average/good/very good. Students were expected to rate their academic performance by comparing it with that of their classmates. Our sample is quite representative of the general population because the rates of housing types were fairly similar to those from census data,[8] with a small Cohen effect size (w = 0.08).[9]

After excluding the poorly answered questionnaires, such as those with response sets and excessive missing answers, 36 612 questionnaires remained (98% of the original sample). Of these, 23 052 questionnaires (63%) from non-smoking students aged 11 to 20 years were analyzed after successive exclusion of current smokers and ex-smokers (n = 4522), students older than 20 years (n = 104), and missing data on academic performance (n = 3020), SHS exposure (n = 109), socioeconomic and demographic information (n = 250), and the identity of co-residing smokers (n = 551). In addition, students who were living with one or more smokers but unexposed to SHS at home in the past 7 days were also excluded (n = 5004), because they might still have been exposed to SHS earlier.

Logistic regression on the basis of generalized estimating equations to control for cluster effect within the same school was used to calculate adjusted odds ratios for poor academic performance caused by exposure to SHS from other people who smoked next to the students at or outside home (categorized in 0, 1-4, and 5-7 days per week). Co-variate adjustments included sex, age, highest parental education, housing type, and, when appropriate, SHS exposures at or outside home. These adjustments took into account the potential effect of socioeconomic status on academic performance.

To compare the effect sizes of SHS exposure at home from different sources, (defined as SHS exposure at home for one or more days per week), students exposed to SHS from co-residing parents, siblings, grandparents, relatives, non-relatives, and non-co-residing visitors (deduced by the reported absence of co-residing smokers but presence of SHS at home in the past 7 days) were compared with the unexposed students (defined as no SHS exposure at home in the past 7 days and did not have any smokers at home) in the logistic regression model adjusting for co-variates as mentioned and mutually adjusting for different sources of exposure. To focus on the SHS exposure at home, the odds ratios for poor academic performance caused by the number of smokers at home (categorized in 0, 1, 2, and ≥3) were also calculated. To further control for potential confounding caused by socioeconomic status, subgroup analyses were conducted, stratified by parental education and the type of housing.

Results

Of all non-smoking students, 19% reported poor academic performance, 68% aspired to achieve a bachelor degree or higher, and 95% realized the harmful effects of SHS. Exposure to SHS at home (36%) and outside the home (66%) was common. One in 3 students lived with one or more smoker (33%), most commonly parents (24%), followed by non-parent family members (9%) and visitors (3%). **Table I** shows that poor academic performance was associated with male sex, older age, lower parental education, temporary housing, exposure to SHS at home and outside the home, and the presence of co-residing smokers.

Non-smoking students who were exposed to SHS at home for one to 4 and 5 to 7 days per week had excess risks (ERs) of poor academic performance of 14% (95% CI, 5%-25%) and 28% (95% CI, 15%-41%), respectively, compared with students who were not exposed to SHS (*P* for trend <.001; **Table II**). Significant ER of 29% (95% CI, 16%-44%) was only observed for SHS exposure outside the home for 5 to 7 days per week (*P* for trend <.001). Similar ERs for SHS

Table I. Prevalence of poor academic performance by basic characteristics

	n	%	χ^2 *P* value
Sex			<.001
Male	10 442	20.4	
Female	12 610	17.7	
Age group			<.001
≤15 years	13 386	16.2	
>15 years	9666	22.7	
Highest parental education level			<.001
Unknown	3938	20.5	
Uneducated or Kindergarten	333	36.6	
Primary school	2763	20.6	
Form 1-3	5237	20.4	
Form 4-5	5997	17.7	
≥Form 6	4784	15.2	
Housing type			<.001
Public housing estate	9718	19.4	
Home ownership scheme	2271	21.0	
Private (owner)	7837	17.3	
Private (tenant)	1878	18.5	
Temporary	161	32.9	
Others	1187	19.9	
SHS exposure at home			<.001
0 day per week	14 804	17.3	
≥1 days per week	8248	21.8	
SHS exposure outside home			<.001
0 day per week	7779	17.3	
≥1 days per week	15 273	19.7	
Smokers at home, n			<.001
0	15 481	17.5	
≥1	7571	21.7	
Type of home smokers			<.001
No smokers	14 804	17.3	
Co-residing parents	5593	19.7	
Co-residing non-parents	2064	26.8	
Visitors	591	23.4	

Table II. Odds ratios of poor academic performance in non-smoking students by days of secondhand smoke exposure per week

Days of SHS exposure per week	n	Poor academic performance (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	*P* for trend
At home					<.001
0 day	14 804	17.3	1.00	1.00	
1-4 days	4122	20.2	1.17 (1.08-1.27)‡	1.14 (1.05-1.25)†	
5-7 days	4126	23.4	1.40 (1.28-1.54)‡	1.28 (1.15-1.41)‡	
Outside home					<.001
0 day	7779	17.3	1.00	1.00	
1-4 days	11 161	18.1	1.06 (0.97-1.15)	0.99 (0.91-1.08)	
5-7 days	4112	24.2	1.49 (1.35-1.66)‡	1.29 (1.16-1.44)‡	
At home§ (excluded SHS exposure outside home)					<.001
0 day	11 232	16.4	1.00	1.00	
1-4 days	2337	19.0	1.15 (1.02-1.29)*	1.15 (1.01-1.30)*	
5-7 days	1623	21.0	1.29 (1.12-1.48)‡	1.28 (1.10-1.48)†	
Outside home§ (excluded SHS exposure at home)					.011
0 day	6980	17.3	1.00	1.00	
1-4 days	8381	18.1	1.00 (0.91-1.10)	0.95 (0.86-1.05)	
5-7 days	2073	24.2	1.39 (1.23-1.57)‡	1.28 (1.13-1.45) ‡	

Odds ratios were adjusted for sex, age, parental education, and housing type. Both SHS at home and outside home were mutually adjusted for.
*$P < .05$.
†$P < .01$.
‡$P < .001$.
§Excluding students who were exposed to SHS for ≥3 days in the other site (at home or outside home) and adjusting for the number of days (0, 1, or 2) exposed in the other site.

exposure at each site were obtained after excluding students with ≥3 days of SHS exposure in the other site.

Non-smoking students who lived with one, two, and ≥3 smokers had ERs of 10% (95% CI, 0.1%-20%), 43% (95% CI, 23%-65%) and 87% (95% CI, 54%-127%), respectively, compared with students who did not live with smokers (*P* for trend <.001; Table III). Living with one more smoker was associated with 15% (95% CI, 11%-20%) higher risk of poor academic performance. The ERs were slightly greater in students with lower parental education and who lived in less expensive housing, but interactions by these socioeconomic factors were insignificant statistically. All the positive linear trends of ER remained significant (*P* for trend <.01) regardless of socioeconomic status.

The ER of poor academic performance was the largest when exposed to SHS from co-residing non-relatives, 95% (95% CI, 50%-154%), followed by siblings, 74% (95% CI, 51%-102%), visitors, 38% (95% CI, 15-65%), co-residing grandparents or relatives, 33% (95% CI, 4%-69%), and parents, 12% (95% CI, 2%-22%), compared with students not exposed to SHS at home (Table IV).

Discussion

Our positive findings of strong dose-response relations suggest that adolescents are vulnerable to poor academic performance from SHS exposure. We have controlled for the potential confounding effects of socioeconomic status[10] by both adjustment and stratification of two locally relevant indicators that adolescents should be able to report, namely parental education and housing type. The coherent findings for SHS exposure outside home, which mainly occurred in indoor environments such as restaurants[11] also support our main results.

There are several potential mechanisms including formation of carboxyhemoglobin in blood,[5] oxidative stress, and inflammation and atherosclerotic processes attributable to other toxic compounds in SHS, such as hydrogen cyanide, arsenic, cadmium, lead, ammonia, and vinyl chloride.[12]

This study is unique in comparing different sources of exposure at home and finding stronger effects by non-parent than parent smokers. This could be because of the longer contact duration of students with non-parents than parents,[13] who typically have long work hours in Hong Kong. However, siblings probably share similar school schedules, and grandparents spend much time at home after retirement. Another possible explanation is that parent smokers might be more likely to smoke inside their own rooms or with air extraction, and the students might share a room with non-parent smokers, including siblings who smoked secretively in the room. SHS would be more concentrated in smaller homes, and it probably explains why stronger effects were observed in less expensive housing types. More detailed information about the smoking practice of different sources would help confirm the aforementioned speculations. Biomarkers such as cotinine are more accurate than self-report as measures of SHS exposure, but they cannot differentiate the place or sources of exposure.[6,14]

Our study has several limitations. The temporality of the association between SHS exposure and poor academic performance could not be ascertained. Although poor academic performance predisposes students to active smoking[15,16] and thus more SHS exposure from smoking peers, there is little incentive for non-smoking students with poor academic performance to increase their noxious exposure to SHS. To reduce any effect of reverse causation, only non-smokers were analyzed.

Table III. Odds ratios of poor academic performance in non-smoking students by the number of smokers at home

Smokers at home, n	n	Poor academic performance (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	*P* for trend
All					<.001
0	15 481	17.5	1	1	
1	6035	20.3	1.16 (1.07-1.26)‡	1.10 (1.00-1.20)*	
2	1075	25.9	1.56 (1.35-1.80)‡	1.43 (1.23-1.65)‡	
≥3	461	30.4	1.99 (1.63-2.42)‡	1.87 (1.54-2.27)‡	
Students with higher parental education§					<.001
0	7980	15.3	1	1	
1	2226	19.5	1.29 (1.14-1.46)‡	1.20 (1.06-1.36)†	
2	390	21.0	1.41 (1.11-1.80)†	1.28 (0.99-1.65)	
≥3	185	27.0	1.99 (1.44-2.75)‡	1.87 (1.35-2.59)‡	
Students with lower parental education§					<.001
0	4901	19.9	1	1	
1	2734	21.0	1.06 (0.94-1.20)	1.07 (0.94-1.23)	
2	496	28.8	1.61 (1.31-1.97)‡	1.59 (1.28-1.96)‡	
≥3	202	34.2	2.08 (1.59, 2.71)‡	2.13 (1.61-2.83)‡	
Students who lived in more expensive housing¶					.001
0	8905	17.1	1	1	
1	2436	20.7	1.21 (1.07-1.36)†	1.08 [0.95, 1.23]	
2	432	22.0	1.28 (1.01-1.61)*	1.13 [0.90, 1.42]	
≥3	213	28.6	1.83 (1.37-2.45)‡	1.66 (1.23-2.25)†	
Students who lived in less expensive housing¶					<.001
0	5778	18.1	1	1	
1	3297	19.9	1.12 (0.98-1.27)	1.10 (0.96-1.27)	
2	588	27.9	1.71 (1.45, 2.01)‡	1.58 (1.33-1.89)‡	
≥3	216	31.5	2.05 (1.49-2.82)‡	1.97 (1.45-2.68)‡	

Odds ratios were adjusted for sex, age, parental education, housing type, and SHS outside home.
*$P < .05$.
†$P < .01$.
‡$P < .001$.
§Higher parental education means Form 4 (grade 10 in United States) or higher; lower parental education means Form 3 (grade 9 in United States) or lower.
¶More expensive housing includes private housing and properties under the home ownership scheme; less expensive housing includes public and temporary housing.

Although academic performance was based on questionnaire survey because of the large sample size, validation studies have shown that self-reported school performance correlated well with school records.[17] Mainstream Hong Kong students should have no problem in reporting their academic performance relative to other students in school because it is common for schools to rank the students by their overall examination results on the report cards. The observed relation of poor academic performance with lower socioeconomic status[10] also provided support as expected to the validity of self-reported academic performance. In future studies, cotinine biomarkers and school records should be used to establish the validity of self-reported SHS exposure and academic performance, respectively.

Many factors may affect academic performance, but our results are unlikely to be explained by respiratory health,[18] sleep quality,[19,20] and psychological health[21] (**Appendix**; available at www.jpeds.com) or affected by the effects of school quality on learning ability[22] because students compared academic performance with their schoolmates in the same school. Although restricting our analyses to nonsmokers only should have largely reduced the confounding effects of unfavorable lifestyle factors associated with smoking,[23-25] residual confounding cannot be ruled out

Table IV. Odds ratios of poor academic performance among non-smoking students by exposure to secondhand smoke at home by the source of exposure

Source of exposure	n	Poor academic performance (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Unexposed	14 804	17.3	1	1
Parents	5593	19.7	1.14 (1.05-1.24)†	1.12 (1.02-1.22)*
Siblings	1053	29.1	1.87 (1.62-2.15)‡	1.74 (1.51-2.02)‡
Grandparents	327	22.3	1.33 (1.04-1.69)*	1.33 (1.04-1.69)*
Relatives	435	22.3	1.33 (1.06-1.68)*	1.33 (1.04-1.69)*
Non-relatives	249	31.3	2.05 (1.59-2.65)‡	1.95 (1.50-2.54)‡
Visitors	591	23.4	1.41 (1.19-1.68)‡	1.38 (1.15-1.65)‡

"Unexposed" represents the reference group that was not exposed to SHS (0 day per week) at home and did not live with any smoker; other categories indicate the presence of different smokers at home in students who were exposed to SHS at home ≥1 days per week.
Odds ratios were adjusted for sex, age, parental education, housing type, SHS exposure outside home, and mutually adjusted for the presence of other smokers.
*$P < .05$.
†$P < .01$.
‡$P < .001$.

because of the crude self-reported measures of socioeconomic status and unmeasured lifestyle factors.

Our measures of SHS exposure at home and outside home in the past 7 days are standard questions used in the Global Youth Tobacco Survey;[7] their positive association (P for trend <.01) with respiratory symptoms in this study (data not shown) also supported their validity.[19,26] Without any major change in tobacco control policy during the survey period, the reported SHS exposure in the past 7 days should reflect the students' usual exposure levels. Besides, few adolescents would be completely unexposed to SHS in densely populated Hong Kong when smoking was still allowed in public places such as restaurants at the time of the survey. Therefore, the reference groups who reported no SHS exposure had probably under-estimated their exposure, and the risk of poor academic performance could be underestimated.[27-29] Finally, excluding questionnaires poorly answered by students might have introduced a selection bias because their academic performances were likely to be poorer. However, such effect should be small because only 2% of the questionnaires were excluded.

Evidence for the harmful effect of SHS exposure on academic performance in adolescents is scarce in Western societies and nil in Asian cities, where education systems are different. In Hong Kong, the education system for secondary school students is highly competitive[30] and stressful,[31] because only 10% of the secondary school students can secure a place for undergraduate degree course in the local universities.[32,33] If exposure to SHS could impair the students' academic performance and hence reduce their chances to succeed, then home smokers are depriving the students' human rights to higher education[34] stipulated in the Universal Declaration of Human Rights—Right to Education (Article 26), which states "higher education shall be equally accessible to all on the basis of merit."[35]

In conclusion, increased SHS exposure is associated with poor academic performance in non-smoking adolescents. The effect is stronger when exposed to non-parent smokers than parent smokers in the same dwelling. Different effects by different smokers would depend on the living environment and smoking practice. This finding is more applicable to small urban dwellings typical of cities in China and Asia than spacious houses in developed countries and may be particularly important to mainland China, where the prevalence of household SHS exposure is high.[36]

Our findings would promote tobacco control measures by alerting clinicians and public health professionals to advise parents or householders, regardless of their smoking status, to eliminate smoking at home and warn their adolescent home members to avoid SHS exposure. Tobacco control advocates, educators, and human right advocators can also make use of our evidence to negotiate an expansion of smoke-free legislation to the home environment. ■

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Appendix. **Odds ratios of poor academic performance among non-smoking students by the number of smokers at home stratified by respiratory symptoms, sleep problem, and academic aspiration**

	Smokers at home, n	n	Poor academic performance (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	*P* for trend
Students who had no persistent respiratory symptoms and sleep problem	0	9801	15.3	1	1	<.001
	1	3563	17.6	1.15 (1.02-1.29)*	1.07 (0.94-1.22)	
	2	571	23.8	1.64 (1.35-2.00)‡	1.53 (1.25-1.89) ‡	
	≥3	241	26.6	1.91 (1.46-2.50) ‡	1.81 (1.38-2.36) ‡	
Students with academic aspiration to achieve university or above	0	11 049	13.7	1	1	<.001
	1	3799	15.1	1.12 (1.00-1.25)*	1.07 (0.94-1.21)	
	2	609	19.5	1.51 (1.21-1.89) ‡	1.42 (1.13-1.77)†	
	≥3	249	24.1	2.03 (1.56-2.64) ‡	1.94 (1.48-2.54) ‡	

Odds ratios were adjusted for sex, age, parental education, housing type and SHS outside home.
Persistent respiratory symptom was defined as frequent cough or sputum in the past 3 months.
Sleep problem was defined as sometimes or always have difficulty to fall or stay asleep.
*$P < .05$.
†$P < .01$.
‡$P < .001$.