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Frequency-risk relationships between second-hand smoke exposure and respiratory symptoms among adolescents in Guangzhou, China

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ABSTRACT

Objectives: Although previous studies have suggested an association between second-hand smoke (SHS) exposure and respiratory symptoms, current evidence is inconsistent. Additionally, it remains unclear whether there are frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

Methods: A cross-sectional survey was conducted using a stratified cluster sampling method to obtain representative students. The univariable and multivariable logistic regression models were fitted to explore the potential frequency-risk relationships between SHS exposure and respiratory symptoms.

Results: Among 3575 students, the prevalence of SHS exposure was 49.5% in indoor public places, 34.5% in homes, 22.7% in indoor campuses, and 29.2% in outdoor campuses. There were significantly increased risks of respiratory symptoms corresponding to SHS exposure in public places (odds ratio [OR]=1.60, 95% CI 1.30-1.95), in homes (OR=1.53, 95% CI 1.25-1.87), in indoor campuses (OR = 1.43, 95% CI 1.14-1.79) and in outdoor campuses (OR = 1.37, 95% CI 1.10-1.69) using no exposure as reference. Notably, we also observed monotonically frequency-risk relationships between setting-specific (e.g., homes, public places, and campuses) SHS exposure and respiratory symptoms.

Conclusion: Our findings suggest that setting-specific SHS exposure is associated with a significant, dose-dependent increase in risk of respiratory symptoms.

Strengths and limitations of this study

- SHS exposure in indoor and outdoor campuses is at a high level, which suggests poor compliance with the full smoke-free ban in schools and supports growing concern about SHS exposure in campuses.
- The most striking findings from this study were that there were monotonically increasing frequency-risk relationships between SHS exposure and respiratory symptoms.
- The findings highlight the need for further longitudinal studies to establish the causal relationship and its biological mechanisms.

INTRODUCTION

It is well established that inhaling second-hand smoke (SHS) is harmful and that no scientific evidence establishes a risk-free level of exposure.[1,2] To note, a retrospective analysis of data from 192 countries revealed that 40% of children (including 35% of female non-smokers and 33% of male non-smokers) were exposed to SHS, which results in an annual estimate of 603000 deaths attributable to SHS.[3] Global youth tobacco surveillance also reported that nearly half the adolescents worldwide were exposed to SHS at home (42.5%) and in public places (55.1%), which constitutes a substantial public health threat and demands urgent intervention.[4] In recent years, much attention has been focused on SHS exposure in public places and in homes, but there is limited information in published reports regarding SHS exposure in indoor and outdoor campuses among adolescents.

Increasing epidemiological studies of adolescents have demonstrated the relations between SHS exposure and respiratory symptoms (such as nose irritation, coughing, and sore throat),[5-8] but current evidence is inconsistent. Some studies demonstrated significant positive associations in adolescents, [9,10] while the report from Malaysian adolescents revealed no association.[11] To note, it was unclear whether there are dose–response relationships between SHS exposure and respiratory symptoms. Furthermore, SHS exposure occurs in varying amounts in public places, homes, and other indoor spaces, but few studies have differentiated SHS exposure in indoor and outdoor to make the setting-specific relations between SHS exposure and respiratory symptoms clearer. Of particular concern is that little is known about the effects of

SHS exposure from indoor and outdoor campuses on respiratory symptoms, although a significant body of literature has associated indoor SHS exposure with respiratory symptoms. This study builds on previous literature to explore setting-specific (e.g., public places, homes, and campuses) and frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

METHODS

Ethics statement

The study was approved by the Ethics Committee of Guangdong Pharmaceutical University, and it was performed in accordance with the approved guidelines. This survey was qualified as involving no risks to participants. All participants provided an informed consent regarding the goals of the study and the willingness to participate.

Study design and data collection

This cross-sectional study was conducted in Guangzhou city, China, from March to April 2016. The target population was high school students in Guangzhou city. A stratified cluster sampling process was used to obtain a representative sample. In the first stage, all high schools were divided into two categories (prestigious or non-prestigious schools) according to level of education and the education quality. Three high schools were randomly sampled from prestigious schools, and four high schools were randomly sampled from non-prestigious schools, with the probability of selection proportional to the number of the schools. In the second stage, classes in the

selected schools were randomly sampled with proportional to school enrollment size, and all students in sampled classes were eligible to participate.

All interviewers in each school were centrally trained to ensure that the survey was carried out according to the protocol and that operation procedures were identical across all areas. After obtaining informed consent, eligible students were asked to complete a face-to-face survey by trained interviewers. A total of 3833 participants were enrolled in the study, and the effective response rate was 95.4% (3657/3833). To note, only non-smokers were included in the analyses and a total of 3575 non-smokers were included in this study.

Study variables

The main outcome variable was self-reported respiratory symptoms. The respiratory symptoms were defined as persistent coughed or sputum for 3 consecutive months in a row during the past 12 months, as had been used in previous studies.[12-14] The main independent variable of respiratory symptoms was self-reported SHS exposure, which was defined as non-smokers' inhalation of the smoke exhaled from smokers on ≥1 day a week for at least the last six months.[1] SHS exposure was asked separately in indoor public places, in homes, in indoor campuses and in outdoor campuses. Frequency of SHS exposure was continuous data (days/week), and was also categorized into three groups: <1 day/week (no exposure), '1-4 days/week' and '5-7 days/week'. Smoking status was classified as non-smokers and smokers (defined as 'has smoked over 100 cigarettes in their lifetime').

Covariates including potential mediators and confounders were chosen a priori on the basis of literature review. Potential covariates in our study included age (year), gender (male or female), grade (4-5 or 1-2), only-child (yes or no), monthly pocket money (<¥100, ¥100-399, or ≥¥400), prestigious school (yes or no), father's education (primary school, middle school, or university and above), mother's education (primary school, middle school, or university and above), and asthma history (yes or no).

Data analysis

All data were entered in duplicate into EpiData version 3.1 database (The EpiData Association, Odense Denmark). The univariable and multivariable logistic regression models were fitted to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for evaluating the frequency-risk relationships between SHS exposure (including ordinal and continuous variables) and respiratory symptoms. Linear trends of SHS exposure were assessed by modeling exposure as continuous variables (arithmetic or logarithmic scale) or ordinal variables in multivariable models. Two-sided p-value of ≤0.05 was regarded as being of statistical significance. All statistical analyses were conducted using Stata version 14.0(StataCorp LP, College Station, Texas, USA).

RESULTS

Characteristics of the sample

Sample characteristics are given in Table 1. A total of 3575 non-smoking students were interviewed, of whom 477 (13.3%) were classified as having respiratory symptoms. Participants' mean age was 15.0±1.8 years, and 50.9% were male students. About 62.2% of the students were the only child in their family and 63.4% from prestigious schools. The prevalence of SHS exposure in indoor public places, homes, indoor campuses, and outdoor campuses was 49.5%, 34.5%, 22.7% and 29.2%, respectively.

Relation between binary SHS exposure and respiratory symptoms

Table 2 shows the relations between binary SHS exposure and respiratory symptoms. The prevalence of respiratory symptoms was significantly higher in students with SHS exposure (OR=1.60, 95% CI 1.30-1.95, for SHS in indoor public places; OR=1.53, 95% CI 1.25-1.87, for SHS in homes; OR = 1.43, 95% CI 1.14-1.79, for SHS in indoor campuses) than in those with no exposure. Similar positive associations were observed among students with SHS exposure in indoor campuses from smoking teachers (OR =1.34, 95% CI 1.05-1.71) or from smoking classmates (OR = 1.54, 95% CI 1.15-2.06). To note, the effects of SHS exposure in outdoor campuses cannot be ignored. Students with SHS exposure in outdoor campuses had significantly higher rates of respiratory symptoms (OR = 1.37, 95% CI 1.10-1.69) as compared with unexposed students, and there were similar positive associations between respiratory symptoms and SHS exposure in outdoor campuses from smoking teachers (OR =1.38, 95% CI 1.09-1.75) or from smoking classmates (OR = 1.33, 95%

CI 1.03-1.71).

Relation between ordinal SHS exposure and respiratory symptoms

Table 3 indicates the relations between ordinal frequency of SHS exposure and respiratory symptoms. Compared with no SHS exposure, ordinal frequency of SHS exposure was associated with respiratory symptoms in a increasing manner (SHS in public places: OR=1 for no exposure, OR=1.50 for 1-4 days/week, OR=1.87 for 5-7 days/week, *p* for linear trend <0.001; SHS in indoor campuses: OR=1 for no exposure, OR=1.24 for 1-4 days/week, OR=1.84 for 5-7 days/week, *p* for linear trend <0.001). When examining the relations by source of exposure, significant increasing trends were observed for SHS exposure in indoor campuses from smoking teachers (*p* for linear trend =0.001) and from smoking classmates (*p* for linear trend =0.005). Additionally, there was a significantly increasing relation between ordinal frequency of SHS exposure in outdoor campuses and respiratory symptoms (OR=1 for no exposure, OR=1.28 for 1-4 days/week, OR=1.56 for 5-7 days/week, *p* for linear trend =0.007), and similar increasing trends were observed for SHS exposure in outdoor campuses from smoking teachers (*p* for linear trend =0.004) and from smoking classmates (*p* for linear trend =0.006). However, no increasing trend was observed for SHS exposure in homes.

Relation between continuous SHS exposure and respiratory symptoms

Table 4 presents the relations between continuous frequency of SHS exposure and

respiratory symptoms. There are significant frequency-risk relationships between indoor SHS exposure and respiratory symptoms (OR = 2.30, 95% CI: 1.67-3.16, for SHS in indoor public places; OR = 1.64, 95% CI: 1.23-2.20, for SHS in homes; OR = 2.09, 95% CI: 1.42-3.07, for SHS in indoor campuses; OR = 1.70, 95% CI: 1.18-2.47, for SHS in outdoor campuses). When examining the relations by source of exposure, there were similar frequency-risk relationships for SHS exposure in indoor or outdoor campuses from smoking teachers or from smoking classmates. Additionally, we observed a monotonically increasing frequency-risk trend for SHS exposure in indoor public places (Figure 1A), in homes (Figure 1B), in indoor campuses (Figure 2A) or in outdoor campuses (Figure 2B). When examining these trends by source of exposure, there were similar increasing frequency-risk trends for SHS exposure from smoking teachers (Figure 3A for indoor SHS and Figure 3B for outdoor SHS) and from smoking classmates (Figure 4A for indoor SHS and Figure 4B for outdoor SHS).

DISCUSSION

This observational study showed that non-smoking students with setting-specific (public places, homes, or campuses) SHS exposure experienced significantly higher risks of respiratory symptoms than those with no exposure. The most striking findings from this study were that there were monotonically increasing frequency-risk relationships between setting-specific SHS exposure and respiratory symptoms. When examining these relations by source of exposure, there were similar monotonically increasing frequency-risk relationships for SHS exposure from smoking teachers and

from smoking classmates.

It is well known that there is no risk-free level of exposure to SHS. According to the partial smoke-free legislation implemented in Guangzhou on 1 September 2010, full smoke-free ban covered indoor campuses, outdoor campuses and most indoor public places, but did not cover homes. It is disappointing that SHS exposure or smoking behaviors in schools were not eliminated, and were still at a high level (22.7% for SHS exposure in indoor campuses; 29.2% for SHS exposure in outdoor campuses). This observation may be due to poor compliance with the full smoke-free ban in campuses, since we observed that SHS exposure among students was mainly from smoking teachers (indoor SHS: 17.8%; outdoor SHS: 18.4%) and smoking classmates (indoor SHS: 11.9%; outdoor SHS:19.6%) in both indoor and outdoor campuses. Similarly, a recent population-based study in Tehran showed that 29.3% and 29.2% non-smoker students have been exposed to SHS from smoking teachers in indoor and outdoor campuses, respectively, and another survey of Chinese college students reported that 37% of non-smokers had SHS exposure from smoking teachers.[15,16] More disappointing was that SHS exposure in indoor public places among students was remarkably high in 49.5% in this study, which is similar to the latest study on adult SHS exposure in Guangzhou (50.3%) and the Global Youth Tobacco Survey (47.8%).[17,18] However, very few respondents (1-2%) reported smoking in enclosed public places in England after the implementation of comprehensive smoke-free legislation covering all enclosed public places and workplaces.[19] These findings point out the urgent need for a comprehensive smoke-free legislation

covering all public places in Guangzhou to protect the public from SHS hazards.

A few published studies have indicated that SHS exposure may be a risk factor of respiratory symptoms, but the potential relation for setting-specific exposure was still unclear.[20-23] Recent studies of Chinese adolescents indicated that there was a positive relation between household SHS exposure and respiratory symptoms, but the relation for SHS exposure in workplaces or in schools was unknown.[20,21] In addition, the surveys of London casino workers and Shanghai workers revealed that there was an association between SHS exposure at work and respiratory symptoms, but the association for SHS exposure in homes or in schools was unknown.[22,23] To note, the influence of SHS exposure from indoor campuses on respiratory symptoms is still unclear, and the potential dose-response association between frequency of SHS exposure and respiratory symptoms is also uncertain. Our study builds on previous literature by exploring the potential dose-response relationships and differentiating SHS exposure in homes, public places, and campuses to make exposure and potential relations clearer. We found that there were positive relations and frequency-risk relationships between setting-specific (public places, homes, or campuses) SHS exposure and respiratory symptoms. When examining the relations by source of exposure, there was still evidence of similar dose-response relationships for SHS exposure in indoor campuses from smoking teachers and smoking classmates. These findings provided new evidence of dose-response relationships between setting-specific SHS exposure and respiratory symptoms among adolescents, and further research is needed to establish the causal relationship and its biological

mechanisms.

Globally, outdoor smoking restrictions are uncommon, though the outdoor-campus smoking bans implemented in Guangzhou City on 1 September 2010. A few published studies have indicated that smoking increases $PM_{2.5}$ concentrations in outdoor areas to levels that are potentially hazardous to health,[24,25] but research linking SHS exposures from outdoor environments to health effects is still limit. Notably, the potential relation between outdoor SHS exposure and respiratory symptoms is still unclear. To our knowledge, this is the first study to reveal the relation between SHS exposure in outdoor campuses and respiratory symptoms among adolescents, and found that outdoor SHS exposure was positively associated with respiratory symptoms in a monotonically increasing trend. When examining the relations by source of exposure, there were still similar frequency-risk relationships for SHS exposure in outdoor campuses from smoking teachers and smoking classmates. These findings provide more evidence for the adverse effects of outdoor SHS exposure on human respiratory symptoms, and also support growing concern about SHS exposure in outdoor campuses.

The most meaningful advantage of this study is that we contributes additionally to the literature by exploring the potential frequency-risk relationships and differentiating SHS exposure in specific settings (e.g., indoor or outdoor; public places, homes, or campuses) and specific sources (e.g., from smoking teachers or from smoking classmates) to make exposure and potential relations clearer. There are also some potential limitations in this study. First, all data were self-reported,

including SHS exposure and respiratory symptoms. For SHS exposure, although biochemical measures can give objective measurements, the biomarkers cannot distinguish the sources of exposure, the key factors in this study. Previous survey has found that school children are capable of reporting their health conditions reliably,[26] and the presence of frequent cough and phlegm was quite obvious to the students and explicit in the question to avoid measurement error. Second, causal association between SHS exposure and respiratory symptoms could not be ascertained due to the cross-sectional design. However, the notion of reverse causation that students with respiratory symptoms deliberately increased their exposure to noxious SHS seems improbable. The strong association observed in other studies also supported our data validity and provided support for the deduction of causation.[20,27,28] Finally, few people would be completely unexposed to SHS in densely populated Guangzhou even now, when smoking was still allowed in public places such as amusement parks, restaurants, workplaces, and so on. Therefore, the control groups who reported no SHS exposure have probably underestimated their exposure, and the risk for respiratory symptoms in these groups would also be underestimated.

In conclusion, SHS exposure in indoor and outdoor campuses is still at a high level, which suggests poor compliance with the full smoke-free ban in schools and supports growing concern about SHS exposure in campuses. Additionally, this study contributes to the literature by finding monotonically increasing frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents in addition to differentiating SHS exposure in specific settings and specific sources to

make these relationships clearer. Future longitudinal studies are needed to establish the causal relationship and its biological mechanisms.

Contributors

CZ, LG, LS, JT, XB, CJ and YX were involved in the design of the study, data analysis and writing of the draft of the manuscript. All the authors read and approved the final version of the manuscript.

Competing interests None.

Ethics approval

The Ethics Committee of Guangdong Pharmaceutical University.

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Figure Legends

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Table 1. Demographic characteristics of the study participants

Characteristics	*n*	%	Characteristics	*n*	%
Respiratory symptoms			Grade		
No	3098	86.7	1-2	2329	65.2
Yes	477	13.3	4-5	1246	34.8
SHS exposure in indoor public places			Only-child		
No	1806	50.5	No	1353	37.8
Yes	1769	49.5	Yes	2222	62.2
SHS exposure in homes			Prestigious school		
No	2342	65.5	No	1307	36.6
Yes	1233	34.5	Yes	2268	63.4
SHS exposure in indoor campuses			Pocket money monthly(¥)		
No	2763	77.3	<100	2039	57.0
Yes	812	22.7	100-399	1125	31.5
SHS exposure in outdoor campuses			≥400	411	11.5
No	2532	70.8	Father's education		
Yes	1043	29.2	Primary school	838	23.4
Gender			Middle school	1215	34.0
Male	1818	50.9	University and above	1522	42.6
Female	1757	49.1	Mother's education		
Asthma history			Primary school	978	27.4
No	3514	98.3	Middle school	1165	32.6
Yes	61	1.7	University and above	1432	40.1

n, number of participants; %, the proportion of participants.

Table 2. Relation between binary SHS exposure and respiratory symptoms

SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in indoor public places				
No	1806	200(11.1)	1.00	1.00
Yes	1769	277(15.7)	1.49(1.23-1.81)	1.60(1.30-1.95)
SHS exposure in homes				
No	2342	275(11.7)	1.00	1.00
Yes	1233	202(16.4)	1.47(1.21-1.79)	1.53(1.25-1.87)
SHS exposure in indoor campuses				
No	2763	338(12.2)	1.00	1.00
Yes	812	139(17.1)	1.48(1.19-1.84)	1.43(1.14-1.79)
SHS exposure in indoor campuses from smoking teachers				
No	2940	369(12.6)	1.00	1.00
Yes	635	108(17.0)	1.43(1.13-1.80)	1.34(1.05-1.71)
SHS exposure in indoor campuses from smoking classmates				
No	3149	399(12.7)	1.00	1.00
Yes	426	78(18.3)	1.54(1.18-2.02)	1.54(1.15-2.06)
SHS exposure in outdoor campuses				
No	2532	309(12.2)	1.00	1.00
Yes	1043	168(16.1)	1.38(1.13-1.69)	1.37(1.10-1.69)
SHS exposure in outdoor campuses from smoking teachers				
No	2917	362(12.4)	1.00	1.00
Yes	658	115(17.5)	1.49(1.19-1.88)	1.38(1.09-1.75)
SHS exposure in outdoor campuses from smoking classmates				
No	2873	366(12.7)	1.00	1.00
Yes	702	111(15.8)	1.29(1.02-1.62)	1.33(1.03-1.71)

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

Table 3. Relation between ordinal frequency of SHS exposure and respiratory symptoms

Frequency of SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in indoor public places				
No exposure	1806	200(11.1)	1.00	1.00
1-4 days/week	1242	184(14.8)	1.40(1.13-1.73)	1.50(1.20-1.86)
5-7 days/week	527	93(17.7)	1.72(1.32-2.25)	1.87(1.41-2.46)
p for linear trend			<0.001	<0.001
SHS exposure in homes				
No exposure	2342	275(11.7)	1.00	1.00
1-4 days/week	570	97(17.0)	1.54(1.20-1.98)	1.62(1.25-2.09)
5-7 days/week	663	105(15.8)	1.41(1.11-1.80)	1.45(1.13-1.87)
p for linear trend			-[b]	-[b]
SHS exposure in indoor campuses				
No exposure	2763	338(12.2)	1.00	1.00
1-4 days/week	539	81(15.0)	1.27(0.98-1.65)	1.24(0.95-1.63)
5-7 days/week	273	58(21.3)	1.94(1.42-2.64)	1.84(1.32-2.56)
p for linear trend			<0.001	<0.001
SHS exposure in indoor campuses from smoking teachers				
No exposure	2940	369(12.6)	1.00	1.00
1-4 days/week	412	59(14.3)	1.16(0.87-1.57)	1.13(0.84-1.53)
5-7 days/week	223	49(22.0)	1.96(1.40-2.74)	1.78(1.25-2.53)
p for linear trend			<0.001	0.001
SHS exposure in indoor campuses from smoking classmates				
No exposure	3149	399(12.7)	1.00	1.00
1-4 days/week	271	45(16.6)	1.37(0.98-1.92)	1.38(0.97-1.97)
5-7 days/week	155	33(21.3)	1.86(1.25-2.78)	1.84(1.20-2.82)
p for linear trend			<0.001	0.005
SHS exposure in outdoor campuses				
No exposure	2532	309(12.2)	1.00	1.00
1-4 days/week	704	105(14.9)	1.26(0.99-1.60)	1.28(1.01-1.64)
5-7 days/week	339	63(18.6)	1.64(1.22-2.21)	1.56(1.13-2.15)
p for linear trend			<0.001	0.007
SHS exposure in outdoor campuses from smoking teachers				
No exposure	2917	362(12.4)	1.00	1.00
1-4 days/week	456	71(15.6)	1.30(0.99-1.72)	1.24(0.94-1.64)
5-7 days/week	202	44(21.8)	1.97(1.38-2.79)	1.74(1.20-2.50)
p for linear trend			<0.001	0.004
SHS exposure in outdoor campuses from smoking classmates				
No exposure	2873	366(12.7)	1.00	1.00
1-4 days/week	451	62(13.8)	1.09(0.82-1.46)	1.16(0.86-1.57)
5-7 days/week	251	49(19.5)	1.66(1.19-2.31)	1.66(1.16-2.39)
p for linear trend			<0.001	0.006

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

[b]: No estimate of p value for linear trend is provide since no linear trend was observed.

Table 4. Relation between continuous frequency of SHS exposure and respiratory symptoms

Frequency of SHS exposure (days/week, logarithmic scale)	β	SE	Z	p-value	OR(95% CI)
SHS exposure in indoor public places					
Univariable regression	0.73	0.16	4.68	<0.001	2.06(1.52-2.80)
Multivariable regression [a]	0.83	0.16	5.11	<0.001	2.30(1.67-3.16)
SHS exposure in homes					
Univariable regression	0.45	0.14	3.14	0.002	1.56(1.18-2.07)
Multivariable regression [a]	0.49	0.15	3.32	0.001	1.64(1.23-2.20)
SHS exposure in indoor campuses					
Univariable regression	0.78	0.18	4.30	<0.001	2.19(1.53-3.12)
Multivariable regression [a]	0.74	0.20	3.77	<0.001	2.09(1.42-3.07)
SHS exposure in indoor campuses from smoking teachers					
Univariable regression	0.82	0.20	4.16	<0.001	2.27(1.54-3.33)
Multivariable regression [a]	0.72	0.21	3.47	0.001	2.06(1.37-3.09)
SHS exposure in indoor campuses from smoking classmates					
Univariable regression	0.71	0.23	3.11	0.002	2.04(1.30-3.20)
Multivariable regression [a]	0.69	0.25	2.77	0.006	2.00(1.22-3.26)
SHS exposure in outdoor campuses					
Univariable regression	0.58	0.17	3.32	0.001	1.79(1.27-2.51)
Multivariable regression [a]	0.53	0.19	2.82	0.005	1.70(1.18-2.47)
SHS exposure in outdoor campuses from smoking teachers					
Univariable regression	0.93	0.20	4.65	<0.001	2.53(1.71-3.74)
Multivariable regression [a]	0.78	0.21	3.72	<0.001	2.20(1.45-3.33)
SHS exposure in outdoor campuses from smoking classmates					
Univariable regression	0.44	0.20	2.22	0.027	1.55(1.05-2.30)
Multivariable regression [a]	0.45	0.22	2.08	0.037	1.58(1.03-2.42)

SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

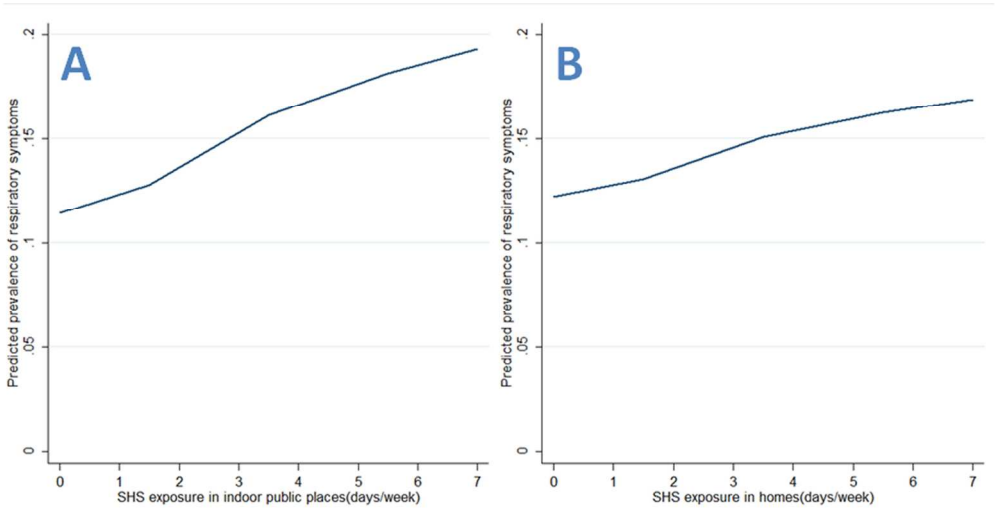

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

124x63mm (300 x 300 DPI)

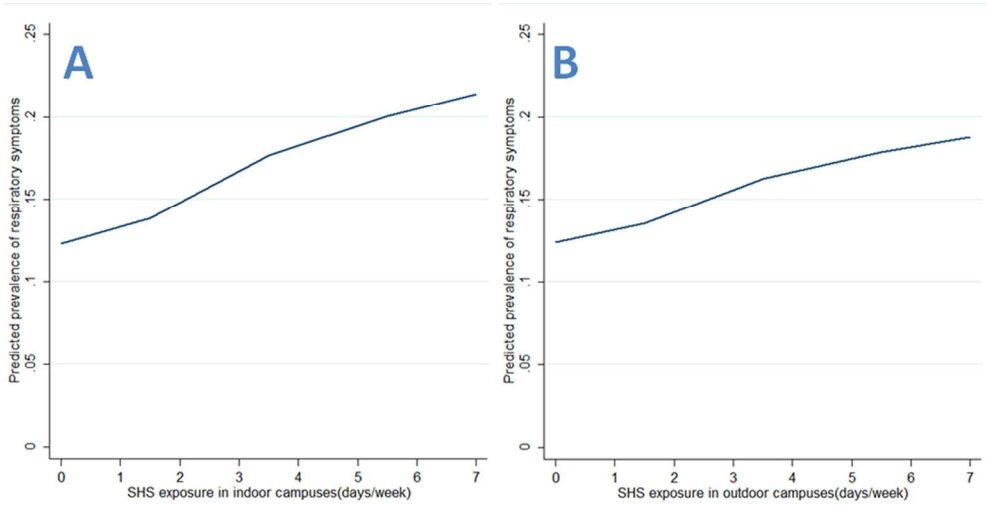

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

125x64mm (300 x 300 DPI)

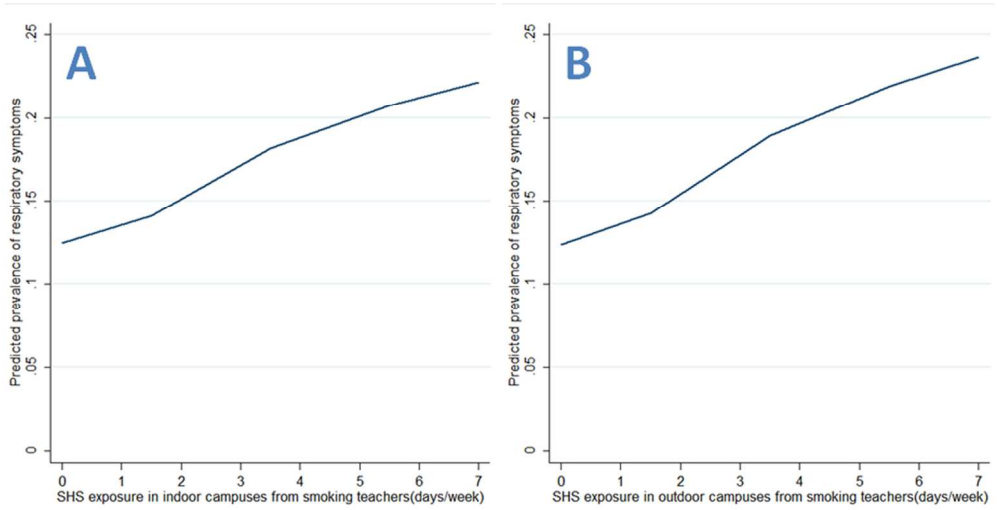

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

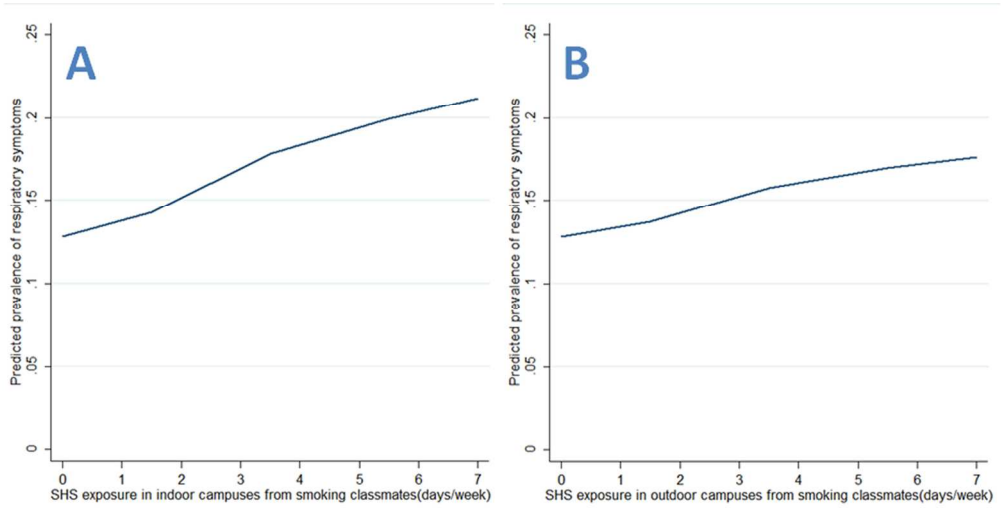

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	No missing data
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	No applicable
		(*e*) Describe any sensitivity analyses	7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	No applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-10
		(*b*) Report category boundaries when continuous variables were categorized	8-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Frequency-risk relationships between second-hand smoke exposure and respiratory symptoms among adolescents: a cross-sectional study in South China

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ABSTRACT

Objectives: Although previous studies have suggested an association between second-hand smoke (SHS) exposure and respiratory symptoms, current evidence is inconsistent. Additionally, it remains unclear whether there are frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

Methods: A cross-sectional survey was conducted using a stratified cluster sampling method to obtain a representative sample of high school students in Guangzhou, China. The respiratory symptoms were defined as persistent cough or sputum for 3 consecutive months during the past 12 months. Self-reported SHS exposure was defined as non-smokers' inhalation of the smoke exhaled from smokers on ≥1 day a week in the past 7 days. The univariable and multivariable logistic regression models were fitted to explore the potential frequency-risk relationships between SHS exposure and respiratory symptoms.

Results: Among 3575 students, the overall prevalence of SHS exposure was 69.2%, including 49.5% in public places, 34.5% in homes, 22.7% in indoor campuses, and 29.2% in outdoor campuses. There were significantly increased risks of having respiratory symptoms corresponding to SHS exposure in public places (odds ratio [OR]=1.60, 95% CI 1.30-1.95), in homes (OR=1.53, 95% CI 1.25-1.87), in indoor campuses (OR = 1.43, 95% CI 1.14-1.79) and in outdoor campuses (OR = 1.37, 95% CI 1.10-1.69) using no exposure as reference. Notably, we observed monotonically frequency-risk relationships between setting-specific (e.g., homes, public places, and campuses) SHS exposure and respiratory symptoms.

Conclusion: Our findings suggest that setting-specific SHS exposure is associated with a significant, dose-dependent increase in risk of respiratory symptoms.

Strengths and limitations of this study

- This study contributes additionally to the literature by exploring the potential frequency-risk relationship between SHS exposure and respiratory symptoms.
- This study differentiates SHS exposure in specific settings and specific sources to make exposure and potential relations clearer.
- SHS exposure and respiratory symptoms were self-reported, which is a limitation.
- Cross-sectional studies do not establish causal relationships but only depict associations. Our findings highlight the need for further longitudinal studies to establish the causal relationship and its biological mechanisms.

INTRODUCTION

It is well established that inhaling second-hand smoke (SHS) is harmful and that no scientific evidence establishes a risk-free level of exposure.[1,2] Notably, a retrospective analysis of data from 192 countries revealed that 40% of children (including 35% of non-smoking women and 33% of non-smoking men) were exposed to SHS, and this exposure is estimated to result in an annual estimate of 603000 deaths attributable to SHS.[3] Global youth tobacco surveillance also reported that nearly half the adolescents worldwide were exposed to SHS at home (42.5%) and in public places (55.1%), which constitutes a substantial public health threat and demands urgent intervention.[4] China is the world's largest producer and consumer of tobacco. The 2010 Global Adult Tobacco Survey reported and 2014 Chinese adolescents Tobacco Survey reported that 72.4% adult and 72.9% adolescents in China were exposed to SHS, suggesting that the tremendous burden from tobacco-induced diseases makes tobacco prevention an essential health priority in China.[5,6] In recent years, much attention has been focused on SHS exposure in public places and in homes, but there is limited reports on SHS exposure in indoor and outdoor campuses among adolescents.

Epidemiological studies of adolescents have explored the relations between SHS exposure and respiratory symptoms (such as nose irritation, coughing, and sore throat) or infection,[7-11] but current evidence is inconsistent. Some studies demonstrated significantly positive associations, [12,13] while the report from Malaysia revealed no association.[14] Recent Chinese studies indicated that there was a positive relation between household SHS exposure and respiratory symptoms in adolescents, but the

relation for SHS exposure in public places or in schools was unknown.[15,16] SHS exposure occurs in varying amounts in public places, homes, and other indoor spaces, but few studies have differentiated SHS exposure in indoor and outdoor to make the setting-specific relations between SHS exposure and respiratory symptoms clearer. Of particular concern is that little is known about the effects of campus SHS exposure on respiratory symptoms. Furthermore, it was unclear whether there are dose–response relationships between SHS exposure and respiratory symptoms. This study builds on previous literature to explore setting-specific (e.g., public places, homes, and campuses) and frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

METHODS

Ethics statement

The study was approved by the Ethics Committee of Guangdong Pharmaceutical University, and it was performed in accordance with the approved guidelines. The goals of the study were given to study participants and they should express their willingness to participate. Before participating, written informed consents were obtained from their parents or guardians.

Study design and data collection

This cross-sectional study was conducted in Guangzhou, China, from March to April 2016. The target population was high school students. A stratified cluster sampling

process was used to obtain a representative sample. Notably, middle schools in most part of China are generally rated by the Bureau of Education as key schools (or prestigious schools) and ordinary schools (or non-prestigious schools) according to level of education and the education quality. In the first stage, all high schools were divided into two categories (prestigious or non-prestigious schools). Three high schools were randomly sampled from prestigious schools, and four high schools were randomly sampled from non-prestigious schools, with the probability of selection proportional to the number of the schools. In the second stage, classes in the selected schools were randomly sampled with proportional to school enrollment size, and all students in sampled classes were eligible to participate.

All interviewers in each school were centrally trained to ensure that the survey was carried out according to the protocol and operation procedures were identical across all areas. After obtaining informed consent, eligible students were asked to complete a face-to-face survey by trained interviewers. A total of 3833 participants were enrolled in the study, and the effective response rate was 95.4% (3657/3833). Only non-smokers were included in the analyses and a total of 3575 non-smokers were included in this study.

Study variables

The main outcome variable was self-reported respiratory symptoms. The respiratory symptoms were defined as persistent cough or sputum for 3 consecutive months during the past 12 months.[17-19] The main independent variable of respiratory

symptoms was self-reported SHS exposure, which was defined as non-smokers' inhalation of the smoke exhaled from smokers on ≥1 day a week in the past 7 days for at least 6 months (first question: "In the past 7 days, how many days did you breathe in SHS in homes (or indoor public places, indoor campuses, outdoor campuses)"; second question for those having SHS exposure: "Did you breathe in SHS in this venue for at least 6 months?"). In order to recall SHS exposure for at least 6 months, we use both curriculum schedules and calendars as an assistive device to facilitate recall the time. Frequency of SHS exposure was continuous data (days/week), and was also categorized into three groups: <1 day/week (no exposure), '1-4 days/week' and '5-7 days/week'. Smoking status was classified as non-smokers and smokers (defined as 'has smoked over 100 cigarettes in their lifetime').

Covariates including potential mediators and confounders were chosen a priori on the basis of literature review. Potential covariates in our study included age (year), gender (male or female), grade (4-5 or 1-2), only-child (yes or no), monthly pocket money (<¥100, ¥100-399, or ≥¥400), prestigious school (yes or no), father's education (primary school, middle school, or university and above), mother's education (primary school, middle school, or university and above), and asthma history (yes or no).

Data analysis

All data were entered in duplicate into EpiData version 3.1 database (The EpiData Association, Odense Denmark). The univariable and multivariable logistic regression

models were fitted to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for evaluating the frequency-risk relationships between SHS exposure (including ordinal and continuous variables) and respiratory symptoms. Linear trends of SHS exposure were assessed by modeling exposure as continuous variables (arithmetic or logarithmic scale) or ordinal variables in multivariable models. Two-sided p-value of <0.05 was regarded as being of statistical significance. All statistical analyses were conducted using Stata version 14.0(StataCorp LP, College Station, Texas, USA).

RESULTS

Characteristics of the sample

A total of 3575 non-smoking students were interviewed, of whom 477 (13.3%) were classified as having respiratory symptoms. Participants' mean age was 15.0±1.8 years, and 50.9% were male students. About 62.2% of the students were the only child in their family and 63.4% from prestigious schools. The overall prevalence of SHS exposure was 69.2%, including 49.5% in indoor public places, 34.5% in homes, 22.7% in indoor campuses, and 29.2% in outdoor campuses (Table 1).

Relation between binary SHS exposure and respiratory symptoms

The prevalence of respiratory symptoms was significantly higher in students with SHS exposure (OR=1.72, 95% CI 1.35-2.17, for SHS in general; OR=1.60, 95% CI 1.30-1.95, for SHS in indoor public places; OR=1.53, 95% CI 1.25-1.87, for SHS in

homes; OR = 1.43, 95% CI 1.14-1.79, for SHS in indoor campuses) than in those with no exposure (Table 2). Similar positive associations were observed in students with SHS exposure in indoor campuses from smoking teachers (OR =1.34, 95% CI 1.05-1.71) or from smoking classmates (OR = 1.54, 95% CI 1.15-2.06). Notably, the effects of SHS exposure in outdoor campuses cannot be ignored. Students with SHS exposure in outdoor campuses had significantly higher rates of respiratory symptoms (OR = 1.37, 95% CI 1.10-1.69) as compared with unexposed students, and there were similar positive associations between respiratory symptoms and SHS exposure in outdoor campuses from smoking teachers (OR =1.38, 95% CI 1.09-1.75) or from smoking classmates (OR = 1.33, 95% CI 1.03-1.71).

Relation between ordinal SHS exposure and respiratory symptoms

Compared with no SHS exposure, ordinal frequency of SHS exposure was associated with respiratory symptoms in an increasing manner (SHS in public places: OR=1 for no exposure, OR=1.50 for 1-4 days/week, OR=1.87 for 5-7 days/week, *p* for linear trend <0.001; SHS in indoor campuses: OR=1 for no exposure, OR=1.24 for 1-4 days/week, OR=1.84 for 5-7 days/week, *p* for linear trend <0.001; Table 3). When examining these relations by source of exposure, significant increasing trends were observed for SHS exposure in indoor campuses from smoking teachers (*p* for linear trend =0.001) and from smoking classmates (*p* for linear trend =0.005). Additionally, there was a significantly increasing relation between ordinal frequency of SHS exposure in outdoor campuses and respiratory symptoms (OR=1 for no exposure,

OR=1.28 for 1-4 days/week, OR=1.56 for 5-7 days/week, *p* for linear trend =0.007; Table 3), and similar increasing trends were observed for SHS exposure in outdoor campuses from smoking teachers (*p* for linear trend =0.004) and from smoking classmates (*p* for linear trend =0.006). However, no increasing trend was observed for SHS exposure in homes.

Relation between continuous SHS exposure and respiratory symptoms

As to continuous SHS exposure, there were significant frequency-risk relationships between indoor SHS exposure and respiratory symptoms (OR = 2.30, 95% CI: 1.67-3.16, for SHS in indoor public places; OR = 1.64, 95% CI: 1.23-2.20, for SHS in homes; OR = 2.09, 95% CI: 1.42-3.07, for SHS in indoor campuses; OR = 1.70, 95% CI: 1.18-2.47, for SHS in outdoor campuses; Table 3). When examining these relations by source of exposure, there were similar frequency-risk relationships for SHS exposure in indoor or outdoor campuses (Table 3). Additionally, we observed a monotonically increasing frequency-risk trend for SHS exposure in indoor public places (Figure 1A), in homes (Figure 1B), in indoor campuses (Figure 2A) or in outdoor campuses (Figure 2B). When examining these trends by source of exposure, there were similar increasing frequency-risk trends for SHS exposure from smoking teachers (Figure 3A for indoor SHS and Figure 3B for outdoor SHS) and from smoking classmates (Figure 4A for indoor SHS and Figure 4B for outdoor SHS).

DISCUSSION

This observational study showed that non-smoking students with setting-specific SHS exposure experienced significantly higher risks of respiratory symptoms than those with no exposure. The most striking findings from this study were that there were monotonically increasing frequency-risk relationships between setting-specific SHS exposure and respiratory symptoms. When examining these relations by source of exposure, there were similar monotonically increasing frequency-risk relationships for SHS exposure from smoking teachers and from smoking classmates.

It is well known that there is no risk-free level of exposure to SHS. Although previous studies have focused on SHS exposure among Chinese adolescents, [15,16,20] there is limited reports regarding SHS exposure in specific settings and specific sources to make exposure clearer. According to the partial smoke-free legislation implemented in Guangzhou on 1 September 2010, full smoke-free ban covered indoor campuses, outdoor campuses and most indoor public places, but did not cover homes. It is disappointing that SHS exposure in schools was not eliminated, and was still at a high level (22.7% for SHS exposure in indoor campuses; 29.2% for SHS exposure in outdoor campuses). This observation may be due to poor compliance with the full smoke-free ban in campuses, since we observed that SHS exposure among students was mainly from smoking teachers and smoking classmates in both indoor and outdoor campuses. Similarly, a recent population-based study in Tehran showed that about 30% non-smoking students have been exposed to SHS from smoking teachers in indoor or outdoor campuses, [21] and another survey of Chinese college students reported that 37% of non-smokers had SHS exposure from smoking teachers. [20] More

disappointing was that SHS exposure in indoor public places among students was remarkably high in 49.5% in this study, which is similar to the latest study on adult SHS exposure in Guangzhou (50.3%) and the Global Youth Tobacco Survey (47.8%).[22,23] After the implementation of a smoke-free legislation, very few respondents (1-2%) reported smoking in public places in England,[24] but smoking behaviors still remained high in public places in Guangzhou because of unwillingness of the policymakers to implement tougher smoke-free policies and poor compliance with the smoke-free law among smokers.[23] These findings reveal that a partial smoke-free legislation has a weak impact on smoking cessation, but a comprehensive smoke-free legislation can substantially attenuate smoking behaviors, which point out the urgent need for a comprehensive smoke-free legislation covering all public places in Guangzhou to protect the public from SHS hazards.

A few published studies have indicated that SHS exposure may be a risk factor of respiratory symptoms, but the potential relation for setting-specific exposure was still unclear.[15,16,25,26] Recent studies of Chinese adolescents indicated that there was a positive relation between household SHS exposure and respiratory symptoms, but the relation for SHS exposure in public places or in schools was unknown.[15,16] In addition, the surveys of London casino workers and Shanghai workers revealed that there was an association between SHS exposure at work and respiratory symptoms, but the association for SHS exposure in homes or in public places was unknown.[25,26] It is noteworthy that the influence of SHS exposure from indoor campuses on respiratory symptoms is still unclear, and the potential dose-response association between

frequency of SHS exposure and respiratory symptoms is also uncertain. Our study builds on previous literature by exploring the potential dose-response relationships and differentiating SHS exposure in homes, public places, and campuses to make exposure and potential relations clearer. We found that there were positive relations and frequency-risk relationships between setting-specific SHS exposure and respiratory symptoms. When examining the relations by source of exposure, there was still evidence of similar dose-response relationships for SHS exposure in indoor campuses from smoking teachers and smoking classmates. These findings provided new evidence of dose-response relationships between SHS exposure and respiratory symptoms among adolescents, and support that the future studies should focus more on differentiating these associations in setting-specific and source-specific exposure. Additionally, further research is needed to establish the causal relationship and potential biological mechanisms, and confirm that elimination of SHS exposure (or stricter smoke-free legislation in Guangzhou) will lead to a reduction in respiratory symptoms among adolescents.

Globally, outdoor smoking restrictions are uncommon, though the outdoor-campus smoking bans implemented in Guangzhou City on 1 September 2010. A few published studies have indicated that smoking increases $PM_{2.5}$ concentrations in outdoor areas to levels that are potentially hazardous to health,[27,28] but research linking SHS exposures from outdoor environments to health effects is still rare. Notably, the potential relation between outdoor SHS exposure and respiratory symptoms is still unclear. To our knowledge, this is the first study to reveal the

relation between SHS exposure in outdoor campuses and respiratory symptoms among adolescents, and found that outdoor SHS exposure was positively associated with respiratory symptoms in a monotonically increasing trend. When examining the relations by source of exposure, there were still similar frequency-risk relationships for SHS exposure in outdoor campuses from smoking teachers and smoking classmates. Although outdoor SHS is more transient than indoor SHS, evidence from review of the research literature on SHS levels in outdoor hospitality venues suggested that tobacco-generated $PM_{2.5}$ in outdoor setting may occasionally be equivalent to or higher than levels observed in indoor setting when smoking is permitted at close proximity.[27] These findings provide more evidence for the adverse effects of outdoor SHS exposure on human respiratory symptoms, and also support growing concern about SHS exposure in outdoor campuses. Future studies on school SHS exposure in adolescents and protective measures against SHS should take outdoor campuses SHS into consideration.

The most meaningful advantage of this study is that we contributes additionally to the literature by exploring the potential frequency-risk relationships and differentiating SHS exposure in specific settings and specific sources to make exposure and potential relations clearer. There are also some potential limitations in this study. First, all data was self-reported, including SHS exposure and respiratory symptoms. For SHS exposure, biochemical measures can give objective measurements, but cannot distinguish the sources of exposure, the key factors in this study. Previous survey has found that school children are capable of reporting their

health conditions reliably,[29] and the presence of frequent cough and phlegm was quite obvious to avoid measurement error. Second, causal association between SHS exposure and respiratory symptoms could not be ascertained due to the cross-sectional design. However, the notion of reverse causation that students with respiratory symptoms deliberately increased their exposure to noxious SHS seems improbable. The strong association observed in other studies also supported our data validity and provided support for the deduction of causation.[15,30,31] Finally, few people would be completely unexposed to SHS in densely populated Guangzhou even now, when smoking was still allowed in public places (e.g., cafes, bars, night clubs, amusement parks, restaurants, and workplaces). Therefore, the control groups who reported no SHS exposure have probably underestimated their exposure, and the risk for respiratory symptoms in these groups would also be underestimated.

In conclusion, SHS exposure in indoor and outdoor campuses is still at a high level, which suggests poor compliance with the full smoke-free ban in schools and supports growing concern about SHS exposure in campuses. Additionally, this study contributes to the literature by finding monotonically increasing frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents in addition to differentiating SHS exposure in specific settings and specific sources to make these relationships clearer. Future longitudinal studies are needed to establish the causal relationship and its biological mechanisms.

Contributors

CZ, LG, LS, JT, XB, CJ and YX were involved in the design of the study, data analysis and writing of the draft of the manuscript. All the authors read and approved the final version of the manuscript.

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Competing interests None.

Ethics approval

The Ethics Committee of Guangdong Pharmaceutical University.

Data sharing statement

No additional data are available.

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Figure Legends

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Table 1. Demographic characteristics of the study participants

Characteristics	*n*	%	Characteristics	*n*	%
Respiratory symptoms			Grade		
No	3098	86.7	1-2	2329	65.2
Yes	477	13.3	4-5	1246	34.8
SHS exposure in general			Only-child		
No	1101	30.8	No	1353	37.8
Yes	2474	69.2	Yes	2222	62.2
SHS exposure in indoor public places			Gender		
No	1806	50.5	Male	1818	50.9
Yes	1769	49.5	Female	1757	49.1
SHS exposure in homes			Pocket money monthly(¥)		
No	2342	65.5	<100	2039	57.0
Yes	1233	34.5	100-399	1125	31.5
SHS exposure in indoor campuses			≥400	411	11.5
No	2763	77.3	Father's education		
Yes	812	22.7	Primary school	838	23.4
SHS exposure in outdoor campuses			Middle school	1215	34.0
No	2532	70.8	University and above	1522	42.6
Yes	1043	29.2	Mother's education		
Asthma history			Primary school	978	27.4
No	3514	98.3	Middle school	1165	32.6
Yes	61	1.7	University and above	1432	40.1

n, number of participants; %, the proportion of participants.

Table 2. Relation between binary SHS exposure and respiratory symptoms

SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in general				
No	1101	106(9.6)	1.00	1.00
Yes	2474	371(15.0)	1.66(1.32-2.08)	1.72(1.35-2.17)
SHS exposure in indoor public places				
No	1806	200(11.1)	1.00	1.00
Yes	1769	277(15.7)	1.49(1.23-1.81)	1.60(1.30-1.95)
SHS exposure in homes				
No	2342	275(11.7)	1.00	1.00
Yes	1233	202(16.4)	1.47(1.21-1.79)	1.53(1.25-1.87)
SHS exposure in indoor campuses				
No	2763	338(12.2)	1.00	1.00
Yes	812	139(17.1)	1.48(1.19-1.84)	1.43(1.14-1.79)
SHS exposure in indoor campuses from smoking teachers				
No	2940	369(12.6)	1.00	1.00
Yes	635	108(17.0)	1.43(1.13-1.80)	1.34(1.05-1.71)
SHS exposure in indoor campuses from smoking classmates				
No	3149	399(12.7)	1.00	1.00
Yes	426	78(18.3)	1.54(1.18-2.02)	1.54(1.15-2.06)
SHS exposure in outdoor campuses				
No	2532	309(12.2)	1.00	1.00
Yes	1043	168(16.1)	1.38(1.13-1.69)	1.37(1.10-1.69)
SHS exposure in outdoor campuses from smoking teachers				
No	2917	362(12.4)	1.00	1.00
Yes	658	115(17.5)	1.49(1.19-1.88)	1.38(1.09-1.75)
SHS exposure in outdoor campuses from smoking classmates				
No	2873	366(12.7)	1.00	1.00
Yes	702	111(15.8)	1.29(1.02-1.62)	1.33(1.03-1.71)

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

Table 3. Relation between frequency of SHS exposure and respiratory symptoms

Frequency of SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in indoor public places				
No exposure	1806	200(11.1)	1.00	1.00
1-4 days/week	1242	184(14.8)	1.40(1.13-1.73)	1.50(1.20-1.86)
5-7 days/week	527	93(17.7)	1.72(1.32-2.25)	1.87(1.41-2.46)
Continuous SHS in indoor public places [b]			2.06(1.52-2.80)	2.30(1.67-3.16)
SHS exposure in homes				
No exposure	2342	275(11.7)	1.00	1.00
1-4 days/week	570	97(17.0)	1.54(1.20-1.98)	1.62(1.25-2.09)
5-7 days/week	663	105(15.8)	1.41(1.11-1.80)	1.45(1.13-1.87)
Continuous SHS in homes [b]			1.56(1.18-2.07)	1.64(1.23-2.20)
SHS exposure in indoor campuses				
No exposure	2763	338(12.2)	1.00	1.00
1-4 days/week	539	81(15.0)	1.27(0.98-1.65)	1.24(0.95-1.63)
5-7 days/week	273	58(21.3)	1.94(1.42-2.64)	1.84(1.32-2.56)
Continuous SHS in indoor campuses [b]			2.19(1.53-3.12)	2.09(1.42-3.07)
SHS exposure in indoor campuses from smoking teachers				
No exposure	2940	369(12.6)	1.00	1.00
1-4 days/week	412	59(14.3)	1.16(0.87-1.57)	1.13(0.84-1.53)
5-7 days/week	223	49(22.0)	1.96(1.40-2.74)	1.78(1.25-2.53)
Continuous SHS in indoor campuses from smoking teachers [b]			2.27(1.54-3.33)	2.06(1.37-3.09)
SHS exposure in indoor campuses from smoking classmates				
No exposure	3149	399(12.7)	1.00	1.00
1-4 days/week	271	45(16.6)	1.37(0.98-1.92)	1.38(0.97-1.97)
5-7 days/week	155	33(21.3)	1.86(1.25-2.78)	1.84(1.20-2.82)
Continuous SHS in indoor campuses from smoking classmates [b]			2.04(1.30-3.20)	2.00(1.22-3.26)
SHS exposure in outdoor campuses				
No exposure	2532	309(12.2)	1.00	1.00
1-4 days/week	704	105(14.9)	1.26(0.99-1.60)	1.28(1.01-1.64)
5-7 days/week	339	63(18.6)	1.64(1.22-2.21)	1.56(1.13-2.15)
Continuous SHS exposure in outdoor campuses [b]			1.79(1.27-2.51)	1.70(1.18-2.47)
SHS exposure in outdoor campuses from smoking teachers				
No exposure	2917	362(12.4)	1.00	1.00
1-4 days/week	456	71(15.6)	1.30(0.99-1.72)	1.24(0.94-1.64)
5-7 days/week	202	44(21.8)	1.97(1.38-2.79)	1.74(1.20-2.50)
Continuous SHS in outdoor campuses from smoking teachers [b]			2.53(1.71-3.74)	2.20(1.45-3.33)
SHS exposure in outdoor campuses from smoking classmates				
No exposure	2873	366(12.7)	1.00	1.00
1-4 days/week	451	62(13.8)	1.09(0.82-1.46)	1.16(0.86-1.57)
5-7 days/week	251	49(19.5)	1.66(1.19-2.31)	1.66(1.16-2.39)
Continuous SHS in outdoor campuses from smoking classmates [b]			1.55(1.05-2.30)	1.58(1.03-2.42)

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

[b]: Use logarithmic exposure (days/week) in the model.

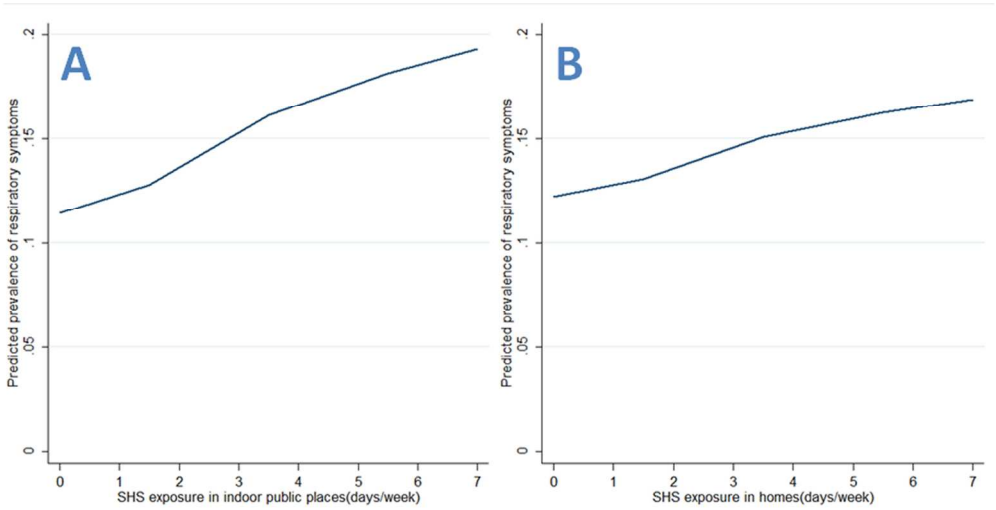

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

124x63mm (300 x 300 DPI)

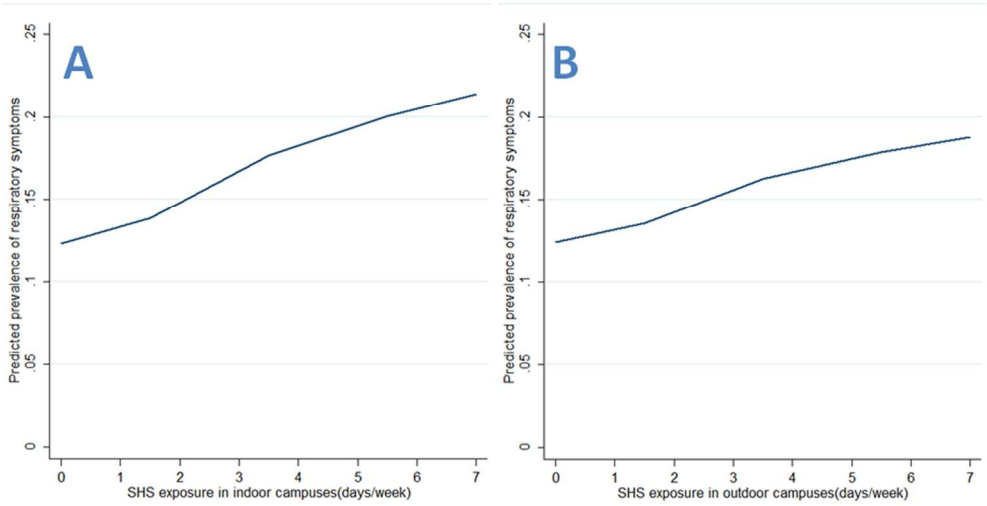

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

125x64mm (300 x 300 DPI)

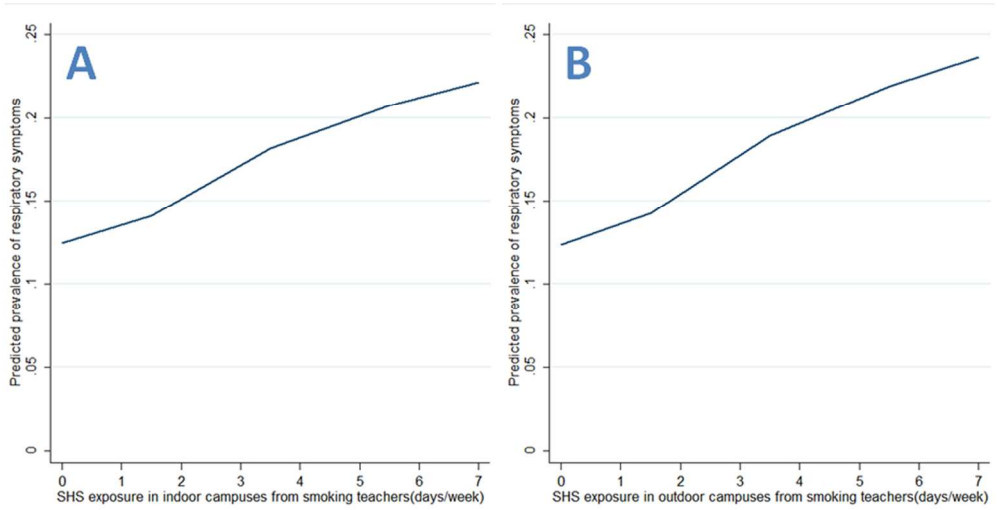

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

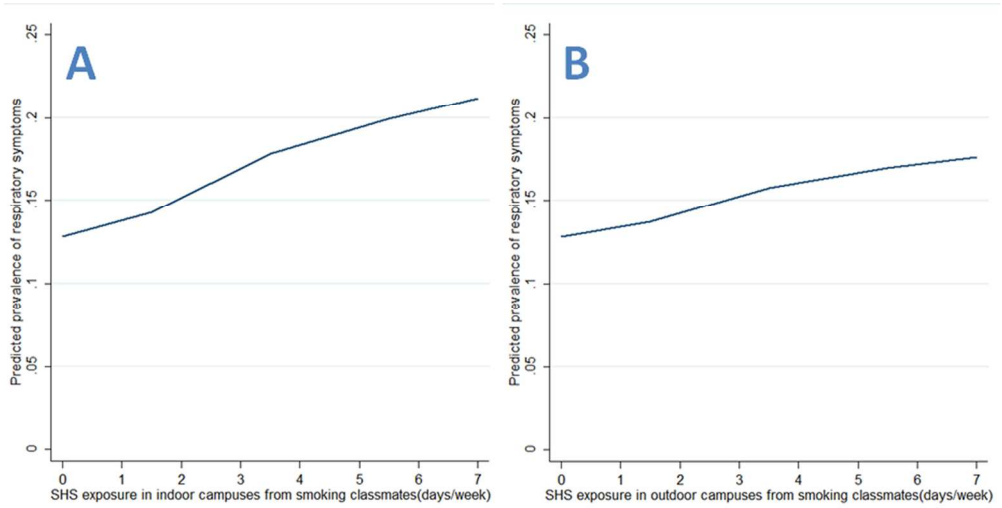

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	No missing data
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	No applicable
		(*e*) Describe any sensitivity analyses	7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	No applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-10
		(*b*) Report category boundaries when continuous variables were categorized	8-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Frequency-risk relationships between second-hand smoke exposure and respiratory symptoms among adolescents: a cross-sectional study in South China

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Frequency-risk relationships between second-hand smoke exposure and respiratory symptoms among adolescents: a cross-sectional study in South China

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ABSTRACT

Objectives: Although previous studies have suggested an association between second-hand smoke (SHS) exposure and respiratory symptoms, current evidence is inconsistent. Additionally, it remains unclear whether there are frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

Methods: A cross-sectional survey was conducted using a stratified cluster sampling method to obtain a representative sample of high school students in Guangzhou, China. The respiratory symptoms were defined as persistent cough or sputum for 3 consecutive months during the past 12 months. Self-reported SHS exposure was defined as non-smokers' inhalation of the smoke exhaled from smokers on ≥1 day a week in the past 7 days. The univariable and multivariable logistic regression models were fitted to explore the potential frequency-risk relationships between SHS exposure and respiratory symptoms.

Results: Among 3575 students, the overall prevalence of SHS exposure was 69.2%, including 49.5% for SHS in public places, 34.5% in homes, 22.7% in indoor campuses, and 29.2% in outdoor campuses. There were significantly increased risks of having respiratory symptoms corresponding to SHS exposure in public places (odds ratio [OR]=1.60, 95% CI 1.30-1.95), in homes (OR=1.53, 95% CI 1.25-1.87), in indoor campuses (OR = 1.43, 95% CI 1.14-1.79) and in outdoor campuses (OR = 1.37, 95% CI 1.10-1.69) using no exposure as reference. Notably, we observed monotonically frequency-risk relationships between setting-specific (e.g., homes, public places, and campuses) SHS exposure and respiratory symptoms.

Conclusion: Our findings suggest that setting-specific SHS exposure is associated with a significant, dose-dependent increase in risk of respiratory symptoms.

Strengths and limitations of this study

- This study aims to explore the potential frequency-risk relationship between SHS exposure and respiratory symptoms, and adds to the literature by focusing on Chinese tobacco control and Chinese youth along with its global context.
- This study differentiates SHS exposure in specific settings and specific sources to make exposure and potential associations clearer.
- SHS exposure and respiratory symptoms were self-reported, which is a limitation.
- Cross-sectional studies do not establish causal relationships but only depict associations. Our findings highlight the need for further longitudinal studies to establish the causal relationship and the biological mechanisms for the impact of SHS.

INTRODUCTION

It is well established that inhaling second-hand smoke (SHS) is harmful and that no scientific evidence establishes a risk-free level of exposure.[1,2] Notably, a retrospective analysis of data from 192 countries revealed that 40% of children (including 35% of non-smoking women and 33% of non-smoking men) were exposed to SHS, and this exposure is estimated to result in an annual estimate of 603000 deaths attributable to SHS.[3] Global youth tobacco surveillance also reported that nearly half the adolescents worldwide were exposed to SHS at home (42.5%) and in public places (55.1%), which constitutes a substantial public health threat and demands urgent intervention.[4] China is the world's largest producer and consumer of tobacco. The 2010 Global Adult Tobacco Survey revealed that 72.4% adults in China were exposed to SHS, and the 2014 Chinese adolescents Tobacco Survey also reported that 72.9% adolescents in China had SHS exposure, suggesting that the tremendous burden from tobacco-induced diseases makes tobacco prevention an essential health priority in China.[5,6] In recent years, much attention has been focused on SHS exposure in public places and in homes, but there is limited reports on SHS exposure in indoor and outdoor campuses among adolescents.

Epidemiological studies of adolescents have explored the associations between SHS exposure and respiratory symptoms (such as nose irritation, coughing, and sore throat) or infection,[7-11] but current evidence is inconsistent. Some studies demonstrated significantly positive associations, [12,13] while the report from Malaysia revealed no association.[14] Recent Chinese studies indicated that there were positive

associations between household SHS exposure and respiratory symptoms in adolescents, but the association for SHS exposure in public places or in schools was unknown.[15,16] SHS exposure occurs in varying amounts in public places, homes, and other indoor spaces, but few studies have differentiated SHS exposure in indoor and outdoor to make the setting-specific relationships between SHS exposure and respiratory symptoms clearer. Of particular concern is that little is known about the effects of campus SHS exposure on respiratory symptoms. Furthermore, it was unclear whether there are dose–response relationships between SHS exposure and respiratory symptoms. This study builds on previous literature to explore setting-specific (e.g., public places, homes, and campuses) and frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents.

METHODS

Ethics statement

The study was approved by the Ethics Committee of Guangdong Pharmaceutical University, and it was performed in accordance with the approved guidelines. The goals of the study were given to study participants and they should express their willingness to participate. Before participating, written informed consents were obtained from their parents or guardians.

Study design and data collection

This cross-sectional study was conducted in Guangzhou, China, from March to April

2016. The target population was high school students. A stratified cluster sampling process was used to obtain a representative sample. Notably, middle schools in most part of China are generally rated by the Bureau of Education as key schools (or prestigious schools) and ordinary schools (or non-prestigious schools) according to level of education and the education quality. In the first stage, all high schools were divided into two categories (prestigious or non-prestigious schools). Three high schools were randomly sampled from prestigious schools, and four high schools were randomly sampled from non-prestigious schools, with the probability of selection proportional to the number of the schools. In the second stage, classes in the selected schools were randomly sampled with proportional to school enrollment size, and all students in sampled classes were eligible to participate.

All interviewers in each school were centrally trained to ensure that the survey was carried out according to the protocol and operation procedures were identical across all areas. After obtaining informed consent, eligible students were asked to complete a face-to-face survey by trained interviewers. A total of 3833 participants were enrolled in this study, and the effective response rate was 95.4% (3657/3833). Only non-smokers were included in the analyses and a total of 3575 non-smokers were included in this study.

Study variables

The main outcome variable was self-reported respiratory symptoms. The respiratory symptoms were defined as persistent cough or sputum for 3 consecutive months

during the past 12 months.[17-19] The main independent variable of respiratory symptoms was self-reported SHS exposure, which was defined as non-smokers' inhalation of the smoke exhaled from smokers on ≥1 day a week in the past 7 days for at least 6 months (first question: "In the past 7 days, how many days did you breathe in SHS in homes (or indoor public places, indoor campuses, outdoor campuses)"; second question for those having SHS exposure: "Did you breathe in SHS in this venue for at least 6 months?"). In order to recall SHS exposure for at least 6 months, we use both curriculum schedules and calendars as an assistive device to facilitate recall the time. Frequency of SHS exposure was continuous data (days/week), and was also categorized into three groups: <1 day/week (no exposure), '1-4 days/week' and '5-7 days/week'. Smoking status was classified as non-smokers and smokers (defined as 'has smoked over 100 cigarettes in their lifetime').

Covariates including potential mediators and confounders were chosen a priori on the basis of literature review. Potential covariates in our study included age (year), gender (male or female), grade (4-5 or 1-2), only-child (yes or no), monthly pocket money (<¥100, ¥100-399, or ≥¥400), prestigious school (yes or no), father's education (primary school, middle school, or university and above), mother's education (primary school, middle school, or university and above), and asthma history (yes or no).

Data analysis

All data were entered in duplicate into EpiData version 3.1 database (The EpiData

Association, Odense Denmark). The univariable and multivariable logistic regression models were fitted to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for evaluating the frequency-risk relationships between SHS exposure (including ordinal and continuous variables) and respiratory symptoms. Linear trends of SHS exposure were assessed by modeling exposure as continuous variables (arithmetic or logarithmic scale) or ordinal variables in multivariable models. Two-sided p-value of <0.05 was regarded as being of statistical significance. All statistical analyses were conducted using Stata version 14.0 (StataCorp LP, College Station, Texas, USA).

RESULTS

Characteristics of the sample

A total of 3575 non-smoking students were interviewed, of whom 477 (13.3%) were classified as having respiratory symptoms. Participants' mean age was 15.0±1.8 years, and 50.9% were male students. About 62.2% of the students were the only child in their family and 63.4% from prestigious schools. The overall prevalence of SHS exposure was 69.2%, including 49.5% for SHS in indoor public places, 34.5% in homes, 22.7% in indoor campuses, and 29.2% in outdoor campuses (Table 1).

Relationship between binary SHS exposure and respiratory symptoms

The prevalence of respiratory symptoms was significantly higher in students with SHS exposure (OR=1.72, 95% CI 1.35-2.17, for SHS in general; OR=1.60, 95% CI

1.30-1.95, for SHS in indoor public places; OR=1.53, 95% CI 1.25-1.87, for SHS in homes; OR = 1.43, 95% CI 1.14-1.79, for SHS in indoor campuses) than in those with no exposure (Table 2). Similar positive associations were observed in students with SHS exposure in indoor campuses from smoking teachers (OR =1.34, 95% CI 1.05-1.71) or from smoking classmates (OR = 1.54, 95% CI 1.15-2.06). Notably, the effects of SHS exposure in outdoor campuses cannot be ignored. Students with SHS exposure in outdoor campuses had significantly higher rates of respiratory symptoms (OR = 1.37, 95% CI 1.10-1.69) as compared with unexposed students, and there were similar positive associations between respiratory symptoms and SHS exposure in outdoor campuses from smoking teachers (OR =1.38, 95% CI 1.09-1.75) or from smoking classmates (OR = 1.33, 95% CI 1.03-1.71).

Relationship between ordinal SHS exposure and respiratory symptoms

Compared with no SHS exposure, ordinal frequency of SHS exposure was associated with respiratory symptoms in an increasing manner (SHS in public places: OR=1 for no exposure, OR=1.50 for 1-4 days/week, OR=1.87 for 5-7 days/week, *p* for linear trend <0.001; SHS in indoor campuses: OR=1 for no exposure, OR=1.24 for 1-4 days/week, OR=1.84 for 5-7 days/week, *p* for linear trend <0.001; Table 3). When examining these associations by source of exposure, significant increasing trends were observed for SHS exposure in indoor campuses from smoking teachers (*p* for linear trend =0.001) and from smoking classmates (*p* for linear trend =0.005). Additionally, there was a significantly increasing relationship between ordinal

frequency of SHS exposure in outdoor campuses and respiratory symptoms (OR=1 for no exposure, OR=1.28 for 1-4 days/week, OR=1.56 for 5-7 days/week, *p* for linear trend =0.007; Table 3), and similar increasing trends were observed for SHS exposure in outdoor campuses from smoking teachers (*p* for linear trend =0.004) and from smoking classmates (*p* for linear trend =0.006). However, no increasing trend was observed for SHS exposure in homes.

Relationship between continuous SHS exposure and respiratory symptoms

As to continuous SHS exposure, there were significant frequency-risk relationships between indoor SHS exposure and respiratory symptoms (OR = 2.30, 95% CI: 1.67-3.16, for SHS in indoor public places; OR = 1.64, 95% CI: 1.23-2.20, for SHS in homes; OR = 2.09, 95% CI: 1.42-3.07, for SHS in indoor campuses; OR = 1.70, 95% CI: 1.18-2.47, for SHS in outdoor campuses; Table 3). When examining these associations by source of exposure, there were similar frequency-risk relationships for SHS exposure in indoor or outdoor campuses (Table 3). Additionally, we observed a monotonically increasing frequency-risk trend for SHS exposure in indoor public places (Figure 1A), in homes (Figure 1B), in indoor campuses (Figure 2A) or in outdoor campuses (Figure 2B). When examining these trends by source of exposure, there were similar increasing frequency-risk trends for SHS exposure from smoking teachers (Figure 3A for indoor SHS and Figure 3B for outdoor SHS) and from smoking classmates (Figure 4A for indoor SHS and Figure 4B for outdoor SHS).

DISCUSSION

This observational study showed that non-smoking students with setting-specific SHS exposure experienced significantly higher risks of respiratory symptoms than those with no exposure. The most striking findings from this study were that there were monotonically increasing frequency-risk relationships between setting-specific SHS exposure and respiratory symptoms. When examining these associations by source of exposure, there were similar monotonically increasing frequency-risk relationships for SHS exposure from smoking teachers and from smoking classmates.

It is well known that there is no risk-free level of exposure to SHS. Although previous studies have focused on SHS exposure among Chinese adolescents, [15,16,20] there is limited reports regarding SHS exposure in specific settings and specific sources. According to the partial smoke-free legislation implemented in Guangzhou on 1 September 2010, full smoke-free ban covered indoor campuses, outdoor campuses and most indoor public places, but did not cover homes. It is disappointing that SHS exposure in schools was not eliminated, and was still at a high level (22.7% for SHS exposure in indoor campuses; 29.2% for SHS exposure in outdoor campuses). This observation may be due to poor compliance with the full smoke-free ban in campuses, since we observed that SHS exposure among students was mainly from smoking teachers and smoking classmates in both indoor and outdoor campuses. Similarly, a recent population-based study in Tehran showed that about 30% non-smoking students have been exposed to SHS from smoking teachers in indoor or outdoor campuses, [21] and another survey of Chinese college students reported that

37% of non-smokers had SHS exposure from smoking teachers. [20] More disappointing was that SHS exposure in indoor public places was remarkably high in 49.5% in this study, which is similar to results from the latest study on Guangzhou adults (50.3%) and the Global Youth Tobacco Survey (47.8%).[22,23] After the implementation of a smoke-free legislation, very few respondents (1-2%) reported smoking in public places in England,[24] but smoking behaviors still remained high in public places in Guangzhou because of unwillingness of the policymakers to implement tougher smoke-free policies and poor compliance with the smoke-free law among smokers.[23] These findings reveal that a partial smoke-free legislation has a weak impact on smoking cessation, but a comprehensive smoke-free legislation can substantially attenuate smoking behaviors, which point out the urgent need for a comprehensive smoke-free legislation covering all public places in Guangzhou to protect the public from SHS hazards.

A few published studies have indicated that SHS exposure may be a risk factor of respiratory symptoms, but the potential relationship for setting-specific exposure was still unclear.[15,16,25,26] Recent studies of Chinese adolescents indicated that there were positive associations between household SHS exposure and respiratory symptoms, but the association for SHS exposure in public places or in schools was unknown.[15,16] In addition, the surveys of London casino workers and Shanghai workers revealed that there was an significant association between SHS exposure at work and respiratory symptoms, but the association for SHS exposure in homes or in public places was unknown.[25,26] It is noteworthy that the influence of SHS exposure from indoor

campuses on respiratory symptoms is still unclear, and the potential dose-response relationship between frequency of SHS exposure and respiratory symptoms is also uncertain. We found that there were positive and frequency-risk relationships between setting-specific SHS exposure and respiratory symptoms. When examining the associations by source of exposure, there was still evidence of similar dose-response relationships for SHS exposure in indoor campuses from smoking teachers and smoking classmates. These findings provide new evidence of dose-response relationships between SHS exposure and respiratory symptoms among adolescents. Further research is needed to establish the causal relationship, and confirm that elimination of SHS exposure (or stricter smoke-free legislation in Guangzhou) will lead to a reduction in respiratory symptoms among adolescents. Although the 2010 report of the Surgeon General explained beyond a shadow of a doubt how tobacco smoke causes disease,[27] additional research should establish the potential biological mechanisms for the impact of SHS.

Globally, outdoor smoking restrictions are uncommon, though the outdoor-campus smoking bans implemented in Guangzhou City on 1 September 2010. A few published studies have indicated that smoking increases $PM_{2.5}$ concentrations in outdoor areas to levels that are potentially hazardous to health,[28,29] but research linking SHS exposures from outdoor environments to health effects is still rare. Notably, the potential relationship between outdoor SHS exposure and respiratory symptoms is still unclear. To our knowledge, this is the first study to reveal the relationship between SHS exposure in outdoor campuses and respiratory symptoms

among adolescents, and found that outdoor SHS exposure was positively associated with respiratory symptoms in a monotonically increasing trend. When examining the associations by source of exposure, there were still similar frequency-risk relationships for SHS exposure in outdoor campuses from smoking teachers and smoking classmates. Although outdoor SHS is more transient than indoor SHS, evidence from review of the research literature on SHS levels in outdoor hospitality venues suggested that tobacco-generated $PM_{2.5}$ in outdoor setting may occasionally be equivalent to or higher than levels observed in indoor setting when smoking is permitted at close proximity.[28] These findings provide more evidence for the adverse effects of outdoor SHS exposure on human respiratory symptoms, and also support growing concern about SHS exposure in outdoor campuses. Future studies on school SHS exposure in adolescents and protective measures against SHS should take outdoor campuses SHS into consideration.

This study adds to the literature by focusing on Chinese tobacco control and Chinese youth along with its global context. Additionally, we contribute additionally to the literature by exploring the potential frequency-risk relationships and differentiating SHS exposure in specific settings and specific sources to make exposure and potential relationships clearer. There are also some potential limitations in this study. First, all data was self-reported, including SHS exposure and respiratory symptoms. For SHS exposure, biochemical measures can give objective measurements, but cannot distinguish the sources of exposure, the key factors in this study. A previous survey has found that school children are capable of reporting their

health conditions reliably,[30] and the presence of frequent cough and phlegm was quite obvious to avoid measurement error. Second, causal association between SHS exposure and respiratory symptoms could not be ascertained due to the cross-sectional design. However, the notion of reverse causation that students with respiratory symptoms deliberately increased their exposure to noxious SHS seems improbable. The strong associations observed in other studies also supported our data validity and provided support for the deduction of causation.[15,31,32] Finally, few people would be completely unexposed to SHS in densely populated Guangzhou even now, when smoking was still allowed in public places (e.g., cafes, bars, night clubs, amusement parks, restaurants, and workplaces). Therefore, the control groups who reported no SHS exposure have probably underestimated their exposure, and the risk for respiratory symptoms in these groups would also be underestimated.

In conclusion, SHS exposure in indoor and outdoor campuses is still at a high level, which suggests poor compliance with the full smoke-free ban in schools and supports growing concern about SHS exposure in campuses. Additionally, this study contributes to the literature by finding monotonically increasing frequency-risk relationships between SHS exposure and respiratory symptoms among adolescents in addition to differentiating SHS exposure in specific settings and specific sources to make these relationships clearer. Future longitudinal studies are needed to establish the causal relationship and the biological mechanisms for the impact of SHS.

Contributors

CZ, LG, LS, JT, XB, CJ and YX were involved in the design of the study, data analysis and writing of the draft of the manuscript. All the authors read and approved the final version of the manuscript.

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Competing interests None.

Ethics approval

The Ethics Committee of Guangdong Pharmaceutical University.

Data sharing statement

No additional data are available.

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Figure Legends

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

Table 1. Demographic characteristics of the study participants

Characteristics	*n*	%	Characteristics	*n*	%
Respiratory symptoms			Grade		
No	3098	86.7	1-2	2329	65.2
Yes	477	13.3	4-5	1246	34.8
SHS exposure in general			Only-child		
No	1101	30.8	No	1353	37.8
Yes	2474	69.2	Yes	2222	62.2
SHS exposure in indoor public places			Gender		
No	1806	50.5	Male	1818	50.9
Yes	1769	49.5	Female	1757	49.1
SHS exposure in homes			Pocket money monthly(¥)		
No	2342	65.5	<100	2039	57.0
Yes	1233	34.5	100-399	1125	31.5
SHS exposure in indoor campuses			≥400	411	11.5
No	2763	77.3	Father's education		
Yes	812	22.7	Primary school	838	23.4
SHS exposure in outdoor campuses			Middle school	1215	34.0
No	2532	70.8	University and above	1522	42.6
Yes	1043	29.2	Mother's education		
Asthma history			Primary school	978	27.4
No	3514	98.3	Middle school	1165	32.6
Yes	61	1.7	University and above	1432	40.0

n, number of participants; %, the proportion of participants.

Table 2. Relationship between binary SHS exposure and respiratory symptoms

SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in general				
No	1101	106(9.6)	1.00	1.00
Yes	2474	371(15.0)	1.66(1.32-2.08)	1.72(1.35-2.17)
SHS exposure in indoor public places				
No	1806	200(11.1)	1.00	1.00
Yes	1769	277(15.7)	1.49(1.23-1.81)	1.60(1.30-1.95)
SHS exposure in homes				
No	2342	275(11.7)	1.00	1.00
Yes	1233	202(16.4)	1.47(1.21-1.79)	1.53(1.25-1.87)
SHS exposure in indoor campuses				
No	2763	338(12.2)	1.00	1.00
Yes	812	139(17.1)	1.48(1.19-1.84)	1.43(1.14-1.79)
SHS exposure in indoor campuses from smoking teachers				
No	2940	369(12.6)	1.00	1.00
Yes	635	108(17.0)	1.43(1.13-1.80)	1.34(1.05-1.71)
SHS exposure in indoor campuses from smoking classmates				
No	3149	399(12.7)	1.00	1.00
Yes	426	78(18.3)	1.54(1.18-2.02)	1.54(1.15-2.06)
SHS exposure in outdoor campuses				
No	2532	309(12.2)	1.00	1.00
Yes	1043	168(16.1)	1.38(1.13-1.69)	1.37(1.10-1.69)
SHS exposure in outdoor campuses from smoking teachers				
No	2917	362(12.4)	1.00	1.00
Yes	658	115(17.5)	1.49(1.19-1.88)	1.38(1.09-1.75)
SHS exposure in outdoor campuses from smoking classmates				
No	2873	366(12.7)	1.00	1.00
Yes	702	111(15.8)	1.29(1.02-1.62)	1.33(1.03-1.71)

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

Table 3. Relationship between frequency of SHS exposure and respiratory symptoms

Frequency of SHS exposure	*n*	Respiratory symptoms (%)	Unadjusted OR(95%CI)	Adjusted OR(95%CI) [a]
SHS exposure in indoor public places				
No exposure	1806	200(11.1)	1.00	1.00
1-4 days/week	1242	184(14.8)	1.40(1.13-1.73)	1.50(1.20-1.86)
5-7 days/week	527	93(17.7)	1.72(1.32-2.25)	1.87(1.41-2.46)
Continuous SHS in indoor public places [b]			2.06(1.52-2.80)	2.30(1.67-3.16)
SHS exposure in homes				
No exposure	2342	275(11.7)	1.00	1.00
1-4 days/week	570	97(17.0)	1.54(1.20-1.98)	1.62(1.25-2.09)
5-7 days/week	663	105(15.8)	1.41(1.11-1.80)	1.45(1.13-1.87)
Continuous SHS in homes [b]			1.56(1.18-2.07)	1.64(1.23-2.20)
SHS exposure in indoor campuses				
No exposure	2763	338(12.2)	1.00	1.00
1-4 days/week	539	81(15.0)	1.27(0.98-1.65)	1.24(0.95-1.63)
5-7 days/week	273	58(21.3)	1.94(1.42-2.64)	1.84(1.32-2.56)
Continuous SHS in indoor campuses [b]			2.19(1.53-3.12)	2.09(1.42-3.07)
SHS exposure in indoor campuses from smoking teachers				
No exposure	2940	369(12.6)	1.00	1.00
1-4 days/week	412	59(14.3)	1.16(0.87-1.57)	1.13(0.84-1.53)
5-7 days/week	223	49(22.0)	1.96(1.40-2.74)	1.78(1.25-2.53)
Continuous SHS in indoor campuses from smoking teachers [b]			2.27(1.54-3.33)	2.06(1.37-3.09)
SHS exposure in indoor campuses from smoking classmates				
No exposure	3149	399(12.7)	1.00	1.00
1-4 days/week	271	45(16.6)	1.37(0.98-1.92)	1.38(0.97-1.97)
5-7 days/week	155	33(21.3)	1.86(1.25-2.78)	1.84(1.20-2.82)
Continuous SHS in indoor campuses from smoking classmates [b]			2.04(1.30-3.20)	2.00(1.22-3.26)
SHS exposure in outdoor campuses				
No exposure	2532	309(12.2)	1.00	1.00
1-4 days/week	704	105(14.9)	1.26(0.99-1.60)	1.28(1.01-1.64)
5-7 days/week	339	63(18.6)	1.64(1.22-2.21)	1.56(1.13-2.15)
Continuous SHS exposure in outdoor campuses [b]			1.79(1.27-2.51)	1.70(1.18-2.47)
SHS exposure in outdoor campuses from smoking teachers				
No exposure	2917	362(12.4)	1.00	1.00
1-4 days/week	456	71(15.6)	1.30(0.99-1.72)	1.24(0.94-1.64)
5-7 days/week	202	44(21.8)	1.97(1.38-2.79)	1.74(1.20-2.50)
Continuous SHS in outdoor campuses from smoking teachers [b]			2.53(1.71-3.74)	2.20(1.45-3.33)
SHS exposure in outdoor campuses from smoking classmates				
No exposure	2873	366(12.7)	1.00	1.00
1-4 days/week	451	62(13.8)	1.09(0.82-1.46)	1.16(0.86-1.57)
5-7 days/week	251	49(19.5)	1.66(1.19-2.31)	1.66(1.16-2.39)
Continuous SHS in outdoor campuses from smoking classmates [b]			1.55(1.05-2.30)	1.58(1.03-2.42)

n, number of participants; SHS, second-hand smoke; OR, odds ratio; CI, confidence interval.

[a]: adjusted for gender (male vs female), grade (4-5 vs 1-2), only-child (yes vs no) and asthma history (yes vs no).

[b]: Use logarithmic exposure (days/week) in the model.

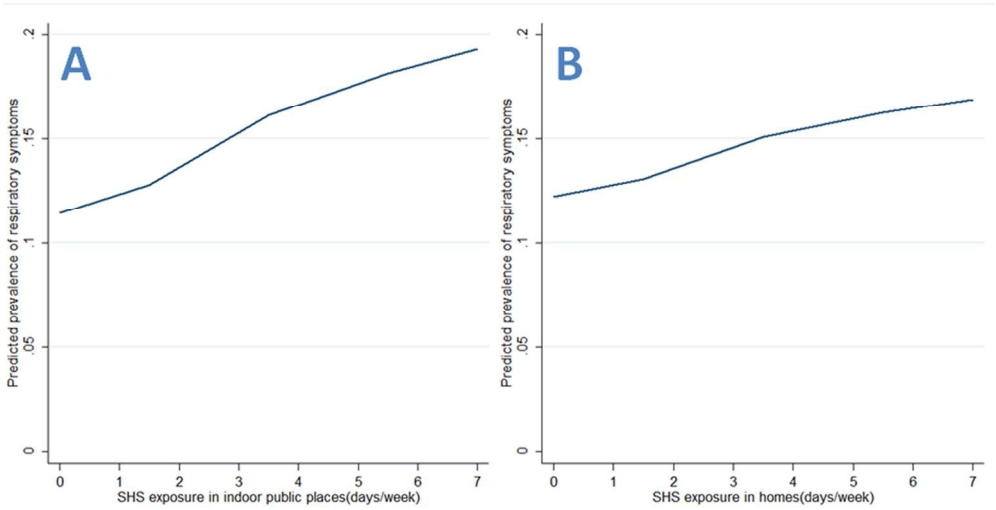

Figure 1. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure (A: exposure in indoor public places; B: exposure in homes).

124x63mm (300 x 300 DPI)

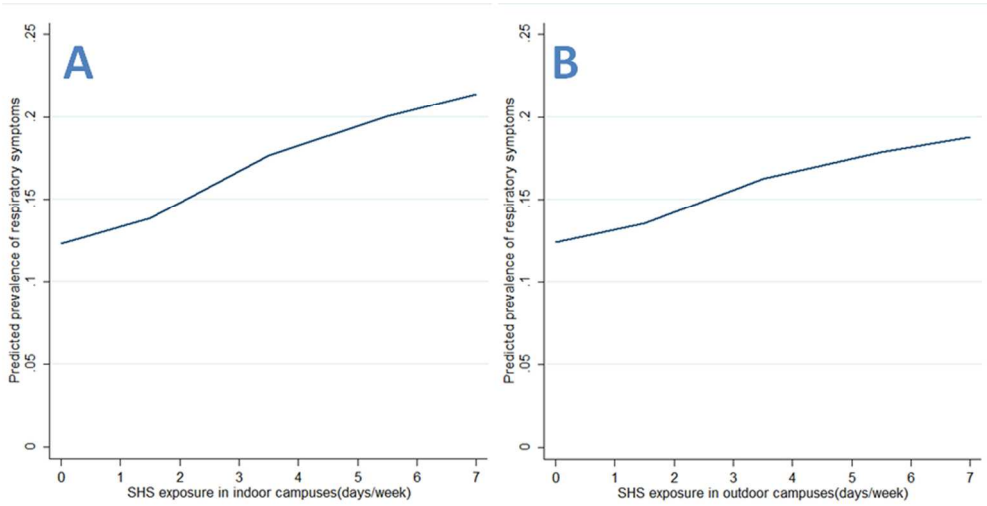

Figure 2. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure in campuses (A: exposure in indoor campuses; B: exposure in outdoor campuses).

125x64mm (300 x 300 DPI)

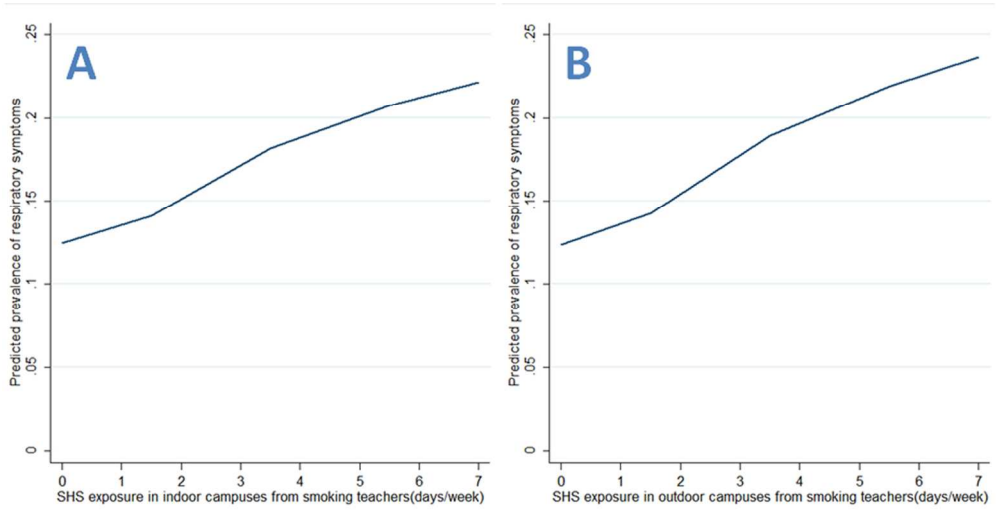

Figure 3. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking teachers (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

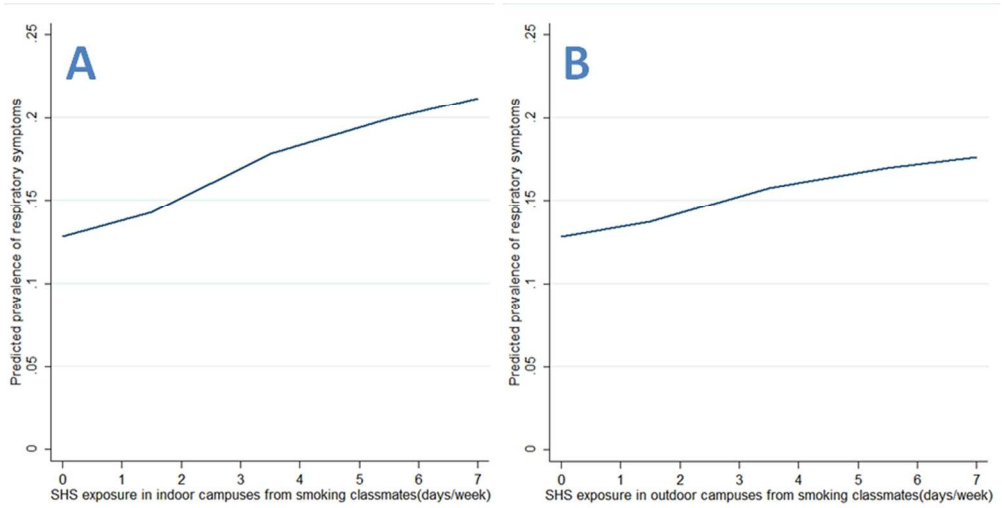

Figure 4. Predicted prevalence of respiratory symptoms based on second-hand smoke exposure from smoking classmates (A: exposure in indoor campuses; B: exposure in outdoor campuses).

124x63mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	No missing data
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	No applicable
		(*e*) Describe any sensitivity analyses	7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	No applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-10
		(*b*) Report category boundaries when continuous variables were categorized	8-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	No funding

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.