Secondhand smoke from multiple sources, thirdhand smoke and respiratory symptoms in Hong Kong adolescents

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ABSTRACT

Introduction: Reports on involuntary tobacco smoke exposure in children have focused mostly on secondhand smoke (SHS) from smoking inside the home. We studied the separate and combined prevalence of SHS exposure from multiple sources and thirdhand smoke (THS) and the associations with respiratory symptoms in Hong Kong adolescents.

Methods: In 2010-11, 61810 Secondary 1 (US Grade 7) to 7 students reported their smoking status, respiratory symptoms and exposure to 4 sources of tobacco smoke in the past 7 days. Weighted prevalence of exposure was calculated. Associations with respiratory symptoms were analysed in 50762 never smokers using logistic regression.

Results: Tobacco smoke exposure at home was 23.2% considering SHS exposure from inside the home, but increased to 33.2% including SHS from neighbours and 36.2% further including THS. Including SHS outside home (55.3%), 63.3% of adolescents were exposed to SHS anywhere or THS at home. In never smokers, SHS from each source and THS at home were linearly associated with respiratory symptoms. Exposure to more sources yielded stronger associations with respiratory symptoms (p for trend<0.001). The adjusted odds ratios (95% CI) were 1.04 (0.97-1.11), 1.12 (1.03-1.22), 1.40 (1.26-1.56) and 1.99 (1.74-2.28) for 1, 2, 3 and 4 sources, respectively.

Conclusions: Although Hong Kong's smoking prevalence is among the lowest in the developed world, over 60% of its adolescents were involuntarily exposed to tobacco smoke from one or more sources with a linear association with respiratory symptoms in never smokers. More stringent policies are needed to protect adolescents from tobacco smoke.

IMPLICATIONS

In a high-density urban setting, involuntary exposure to tobacco smoke in adolescents can be much higher than the smoking prevalence of the general population, especially if secondhand smoke exposure from multiple sources and thirdhand smoke are also considered. Such exposures have important health implications as demonstrated by their linear associations with respiratory symptoms. Tobacco control measures effective in reducing smoking prevalence may have little effect in reducing adolescent exposure to tobacco smoke, especially in the private home, in which other public health strategies are urgently needed.

INTRODUCTION

Reports on the harms of involuntary tobacco smoke exposure in adolescents usually focus only on secondhand smoke (SHS) at home from someone smoking inside the home, but seldom on other sources of exposure at or outside home concurrently.[1,2] SHS at home can also come from neighbours through shared hallways and open doors and windows as evidenced by objective measurements and self-reported data,[3-5] and such exposure was associated with respiratory symptoms in adolescents.[4] SHS exposure outside home is another prevalent source of tobacco smoke exposure in adolescents,[6] but reports on its association with respiratory symptoms were scarce.[7,8]

Furthermore, tobacco smoke exposure does not stop as the visible smoke vanishes, but can continue for months after the burning tobacco extinguishes.[9] The term "thirdhand smoke (THS)" has emerged in recent years to describe the smoke residues that linger on surfaces and in dust after smoking.[9] Indoor walls and typical household items, such as curtains, carpets and upholstery of sofa and chairs, are reservoirs of THS.[10] While smokers may protect family members against SHS at home by smoking outside, their exhaled breaths, skin,

hair and clothing may transfer smoke residues back into the home, exposing the family to THS.[9,11-14] Greater levels of THS contamination were detected in homes with higher household cigarette consumption despite self-imposed home smoking ban.[14] After deposition, THS may be re-emitted into the gas phase or re-suspended as ultrafine particles,[15,16] or react with ambient pollutants to form carcinogenic tobacco-specific nitrosamines (TSNAs), including one (1-(N-methyl-N-nitrosamino)-1-(3-pyridinyl)-4-butanal) that is absent in SHS.[17] Unlike SHS, its routes of exposure are not limited to inhalation, but also ingestion of THS-loaded dust and dermal contact with contaminated surfaces.[16] The exposure levels to nicotine and TSNAs can be much higher from THS than from SHS in both children and adults.[18] Laboratory studies using animal models suggested that THS exposure might affect lung development and contribute to lung diseases, cardiovascular disease, poor wound healing and hyperactivity.[10,19] An observational study in Korea also found that children exposed to THS or SHS had higher risks of lower respiratory symptoms.[20] However, being a hidden source of tobacco smoke, THS exposure and its harms have been overlooked in many other studies.

Involuntary tobacco smoke exposure can arise from multiple sources, and exposure to more sources may pose a higher health risk. The smoking prevalence in Hong Kong is among the lowest (around 11% in 2007-15) in the developed world after 3 decades of strong tobacco control measures, and statutory smoke-free areas in public places have been substantially extended since 2007.[21-23] Despite the low smoking prevalence and extensive coverage of smoke-free areas, SHS exposure remains prevalent such that one-third of children were exposed to SHS from nearby smoking inside or outside home in 2008,[7] not to mention SHS from neighbours and THS. To our knowledge, studies on the adverse health outcomes of tobacco smoke exposure in adolescents have predominantly focused on SHS from inside the home and rarely on other sources, especially THS, and none has combined multiple sources

when assessing the prevalence and health risks. We therefore investigated the prevalence of exposure to SHS at home from inside the home, SHS at home from neighbours, THS at home and SHS outside home separately and collectively in Hong Kong adolescents, and the associations with respiratory symptoms in never smokers.

METHODS

An anonymous standardised questionnaire adapted from the Global Youth Tobacco Survey (GYTS) [6] was administered in 79 secondary schools randomly selected from all the 18 districts in Hong Kong with a probability proportional to the total number of schools in the respective districts in 2010-11. The secondary education in Hong Kong comprised 7 years of schooling at the time of survey; we invited all Secondary 1 (US grade 7) to 7 students (97.3% response rate) of the selected schools to complete the questionnaire. As approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster, parents received an invitation letter from the research team via students and they could decline by asking their children to return a blank answer sheet during the survey. The questionnaire was administered in classrooms with a separate answer sheet that show the numbers but not wordings of response options. Teachers were present to maintain order without patrolling near students. The survey was voluntary that, even with parental consent, students could decline participation by returning a blank answer sheet. To encourage candid reporting, students were instructed to answer independently and assured of anonymity and confidentiality. Research personnel collected and sealed the answer sheets in front of the students immediately after the survey.

Students were provided with 6 options, including “never smoking”, experimental smoking”, “ex-occasional smoking”, “ex-daily smoking”, “occasional smoking”, and “daily smoking”,

to describe their smoking status. They were also asked the number of days that they smoked in the past 30 days. Those choosing "never smoking" and reporting no smoking in the past 30 days were defined as never smokers. Smoking status of family members was also recorded. Families having any smokers who lived with the students were regarded as "smoking families", and otherwise as "non-smoking families".

SHS exposure at home from inside the home was assessed by the question "In the past 7 days, how many days have people smoked near you at home?"; SHS exposure at home from neighbours was assessed by "In the past 7 days, how many days did you breathe in SHS at home that came from outside home (eg, neighbouring flats)?"; THS exposure at home was assessed by "In the past 7 days, how many days did you smell cigarette smoke at home when nobody was smoking at home, but someone might have smoked earlier?"; and SHS exposure outside home was assessed by "In the past 7 days, how many days have someone smoked near you outside home?". The response options for each exposure, 0 day to 7 days, were categorised into "0 day/week" (reference), "1-4 days/week" and "5-7 days/week". Respiratory symptoms were defined as having cough or sputum for 3 consecutive months in the past 12 months.[7,8,24] Socio-demographic characteristics, including sex, age, place of birth, parental education and housing type, were also recorded.

SPSS 20 and STATA 10 were used for analysis. Descriptive data were weighted by age, sex and grade distribution of Hong Kong students in 2010-11 provided by the government Education Bureau. Prevalence of exposure to the 4 sources of tobacco smoke, SHS at home from inside the home and neighbours, THS at home and SHS outside home, as separate and combined variables, and prevalence of THS exposure by SHS exposure in all students and by family smoking status were calculated. Logistic regression yielded adjusted odds ratios (AORs) of respiratory symptoms for exposure to each source and the total number of sources

of tobacco smoke in never smoking students, compared with no corresponding exposure. Age, sex, housing type, highest parental education and school clustering effect were adjusted for.

RESULTS

A total of 61810 students were analysed after excluding those (0.4%) with missing information on age, grade, sex or over half of all items. The mean age (SD) was 14.7 (±2.0) years and 50.8% were boys. Table 1 shows that 74.6% of students had parents with at least secondary education, and 48.8% were living in public or subsidised housing.

Overall, 63.3% of students were exposed to SHS anywhere or THS at home (Table 2). SHS exposure at home from inside the home and from neighbours were reported by 23.2% and 17.1% of students, respectively. One-third (33.2%) were exposed to either or both sources of SHS at home. THS exposure at home, referring to smelling residual cigarette smoke, was reported by 16.9% of students, including 12.3% for 1-4 days and 4.6% for 5-7 days/week. The prevalence might have been underestimated as THS exposure at weak and unnoticeable levels could not be captured by our question. Including both SHS and THS, the prevalence of involuntary tobacco smoke exposure at home was 36.2%. Over half the students (55.3%) were exposed to SHS outside home. Table 3 shows that students exposed to any SHS, whether at or outside home, smelt THS at home more commonly than those unexposed. Four in 10 students (41.2%) exposed to any SHS at home but only 4.6% of those unexposed reported THS exposure at home. Such pattern was also observed when stratified by family smoking status. In smoking families, 48.4% of students exposed to SHS from inside the home were reportedly exposed to THS. Despite no SHS exposure from inside the home, still a much higher proportion of students in smoking families (23.3%) reported THS exposure at

home than students in non-smoking families (3.2%). In non-smoking families, students exposed to neighbour SHS (16.7%) smelt THS at home more commonly than those unexposed (1.8%). Around a quarter of all students exposed to SHS outside home (25.9%) reported THS exposure at home.

In never smokers (n=50762), 18.8% were exposed to SHS from inside the home, 15.0% to SHS from neighbours, 13.4% to THS at home and 53.1% to SHS outside home (Table 4). In the crude logistic regression model, the associations of respiratory symptoms for different SHS exposure and THS exposure at home were all significant. When different exposures were mutually adjusted and socio-demographic characteristics and school clustering effect were also adjusted for, the associations for exposure to any SHS at home from inside the home and neighbours remained significant, with AORs (95% CI) of 1.13 (1.05-1.21) and 1.23 (1.14-1.32). The association for THS exposure at home was also significant, with AORs (95% CI) of 1.22 (1.12-1.34) for any exposure, 1.19 (1.07-1.32) for 1-4 days and 1.29 (1.11-1.50) for 5-7 days (p for trend<0.001). Table 4 also shows the associations between the number of sources of tobacco smoke exposure and respiratory symptoms in never smokers. In both crude and adjusted models, students exposed to more sources of tobacco smoke had higher odds of respiratory symptoms, compared with those unexposed to SHS anywhere and THS at home. Significant associations were observed for exposure to more than 1 source of tobacco smoke. The AOR (95% CI) was 1.12 (1.03-1.22) for any 2 sources, 1.40 (1.26-1.56) for any 3 sources and 1.99 (1.74-2.28) for all the 4 sources (p for trend<0.001).

DISCUSSION

This study is the first to include SHS from different sources and THS as separate and combined variables in investigating involuntary tobacco smoke exposure and its associations with respiratory symptoms in adolescents. Over 60% of Hong Kong adolescents were

involuntarily exposed to tobacco smoke. The exposure at home was 56% more prevalent when SHS from neighbours and THS were considered in addition to SHS from inside the home ((36.2-23.2)/23.2). Students unexposed to SHS from inside the home in smoking families reported THS exposure at home far less commonly than those exposed (23.3% vs 48.4%), but still much more commonly than their counterparts in non-smoking families (3.2%). This is consistent with a Western study which found that the nicotine exposure level in infants in smoking families with home smoking ban were lower than that in smoking families without such ban but higher than that in non-smoking families.[13] Our results are also in line with hair nicotine and cotinine tests in other studies which revealed involuntary tobacco smoke exposure in children whose family members smoked only outside home.[25,26]

Smoking inside the home is undoubtedly a contributor to THS exposure at home. THS can adhere on common household fabrics for more than 1.5 years,[18] and its accumulation can reflect cumulative smoking habits inside the home.[27] Even if smoking at home is not allowed, THS may still get into the home. Detectable levels of surface nicotine in smoke-free hospital settings visited by smokers implied the feasibility of THS transfer through clothing of smokers.[12] Smokers may also transport THS back into the home through skin and exhaled breaths, as suggested by the nicotine detected on fingers of smokers and the evidence that the lungs take up to 90 seconds to wash out tobacco smoke after the last cigarette puff.[11,13,28] Household THS contamination in heavy smoking families with home smoking ban could be comparable to that in light smoking families without the ban,[14] indicating the plausibility of smelling residual smoke in homes of heavy smoking families even no smoking has occurred inside.

THS at home may also be attributed to SHS from neighbours. We found that, regardless of family smoking, THS exposure was more commonly reported by students exposed to

neighbour SHS than those unexposed. Homes in Hong Kong are typically closely packed in multiunit housing,[29,30] where the short interunit distance may facilitate SHS infiltration from neighbouring homes.[5] Self-reported frequent exposure to neighbour SHS was found associated with higher air nicotine concentration at home.[31] THS from neighbour SHS adhering on indoor surfaces may accumulate to give noticeable smell of tobacco smoke, particularly in homes with more neighbour SHS exposure.

In adolescents who had never smoked, those involuntarily exposed to any tobacco smoke were more likely to have persistent respiratory symptoms. The association of SHS exposure with respiratory symptoms was dose-dependent, in line with other studies in children, adolescents and adults.[2,8,24,32-34] Similarly, the dose-response relation was observed between THS exposure at home and respiratory symptoms. Our findings are largely consistent with a Korean study in children that both SHS and THS exposure at home were associated with respiratory symptoms.[20] However, while we found that the magnitude of the association for THS exposure was comparable with that for SHS exposure, the Korean study found that the association was weaker for THS than SHS exposure.[20] Such discrepancy is suspected to result from the different measures of SHS and THS exposure used. SHS and THS exposure in our study were respectively defined by self-report of breathing in SHS and smelling residual cigarette smoke at home, whereas in that study parents reported whether they had smoked at home in the presence of children.[20] Potential sources of SHS and THS at home include other family members and neighbours who smoke in addition to smoking parents. Besides, as explained earlier, THS exposure is still possible even if children are not directly exposed to SHS. Our use of information reported by adolescents themselves and not confining SHS and THS sources to parents might have led to the difference observed. Moreover, THS gives low-level exposure over prolonged periods,[9] and can contribute to up to 60% of the total harms caused by indoor exposure to tobacco-related pollutants.[35] The

effect size of the association with respiratory symptoms for THS exposure being comparable to that for SHS exposure is thus plausible.

The smoking prevalence in Hong Kong is among the world's lowest given the comprehensive tobacco control measures.[22,23] The smoke-free areas were greatly extended to most indoor public places, all indoor restaurants and workplaces, and some outdoor places in 2007, and progressively extended to cover more public places afterwards.[36] However, still a substantial proportion of adolescents were exposed to tobacco smoke. Respiratory problems were the top reason for which Hong Kong adolescents consulted doctors or took self-medication.[37] Exposure to more sources of tobacco smoke was more strongly associated with respiratory symptoms, suggesting the need for more stringent tobacco control policies. Smoke-free housing policy banning smoking in private homes and shared areas should be considered. A comprehensive smoke-free housing policy could reduce SHS exposure in both smoking and non-smoking homes,[38] and was associated with cessation-related outcomes.[39] Conversely, restricting smoking only in shared areas might increase smoking in private homes and increase the odds of SHS transfer from smoking homes to others.[40] Longitudinal data also showed reduced THS contamination in smoking families which banned smoking at home.[14] Belief that tobacco smoke exposure is harmful was associated with adoption of home smoking ban.[41,42] Our findings provide strong evidence to support for comprehensive smoke-free housing policies, which should ban smoking in not only shared areas but also private homes.

The prevalences of tobacco smoke exposure from different sources were lower in never smokers than all students, implying more prevalent exposure in smokers than never smokers. Previous studies have also observed stronger associations of SHS exposure with respiratory symptoms and medical services use in adolescent smokers than never smokers, suggesting

heavier SHS exposure in smokers.[8,43] Future studies may investigate whether smokers also have higher odds of respiratory symptoms in relation to THS exposure at home and the number of sources of tobacco smoke exposure.

Our study had some limitations. First, all data were self-reported. Although smoking might be a sensitive issue to students, we assured them of anonymity and confidentiality to encourage them to report the truth. Tobacco smoke exposure was not objectively measured because the sample size was large, and biomarkers such as hair nicotine levels could not differentiate the locations and sources of exposure. Standard questions in the GYTS were adapted to ask about SHS exposure at home from inside the home and SHS exposure outside home,[6] and were modified to ask about neighbour SHS and THS exposure at home. Report of neighbour SHS and THS exposure at home by students in non-smoking families agreed with the objective evidence in other studies which suggested SHS infiltration from neighbouring homes and THS contamination in non-smoking homes,[3,5,28,44] supporting the validity of our measures. We defined respiratory symptoms as persistent cough and phlegm, which were obvious to adolescents and clearly stated in the question to avoid measurement error. The dose-response associations with respiratory symptoms found for both SHS and THS exposure in this study were expected and consistent with those in other studies,[2,8,24,32-34] indirectly supporting our data validity on respiratory symptoms and different sources of tobacco smoke exposure. However, the prevalence of THS exposure at home and the association with respiratory symptoms should be interpreted with caution. The prevalence might have been underestimated as the definition used, detection of residual cigarette smell, limited the possibility of capturing THS exposure at weak and unnoticeable levels. Besides, it takes 2 to 21 hours for SHS to transit into THS depending on the criteria to define the transition, during which they coexist.[35] Our definition of THS may not completely differentiate it from SHS exposure. Second, causal inference between tobacco smoke

exposure and respiratory symptoms based on cross-sectional data is cautioned. Third, although we restricted to never smoking students and adjusted for potential confounders when analysing the associations between tobacco smoke exposure and respiratory symptoms, residual confounding due to unmeasured variables, such as exposure to THS outside home and air pollution, cannot be ruled out. Future studies may collect data on and control for these variables.

CONCLUSIONS

Over 60% of Hong Kong adolescents were exposed to SHS anywhere or THS at home. Similar to SHS exposure, THS exposure at home was dose-dependently associated with respiratory symptoms in never smokers. Exposure to more sources of tobacco smoke was associated with higher odds of respiratory symptoms. Our findings have provided strong evidence on the harms of the easily overlooked THS among other sources of tobacco smoke exposure, and highlight the need for more stringent tobacco control policies to protect adolescents against the exposure at and outside home.

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DECLARATION OF INTEREST

None to declare for all authors.

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Table 1. Basic characteristics of students (N=61810)

Basic characteristics	%
Sex	
Boys	50.8
Girls	49.3
Age group, years	
≤15	66.1
>15	33.9
Place of birth	
Hong Kong	77.5
Mainland China/Macau/Taiwan	19.3
Other places	3.2
Highest parental education	
Primary/no formal education	10.3
Secondary	53.6
Tertiary	21.0
Unknown	15.2
Housing type	
Public	37.2
Subsidised	11.6
Private	37.7
Temporary/others/unknown	13.6
Family smoking	
No	61.2
Yes	38.9
Student smoking status	
Never smokers	84.3
Ever smokers	15.8

Data were weighted by age, sex and grade

Table 2. Prevalence of SHS exposure anywhere and THS exposure at home (N=61810)

	At home					Outside home	SHS anywhere or THS at home
	SHS			THS	Any	SHS	
Exposure (days/week)	From inside the home	From neighbours	Any				
0	76.8	82.9	-	83.1	-	44.8	-
1-4	12.4	13.5	-	12.3	-	39.2	-
5-7	10.8	3.6	-	4.6	-	16.1	-
Any	23.2	17.1	33.2	16.9	36.2	55.3	63.3

Percentages were weighted by age, sex and grade

Table 3. Prevalence of THS exposure at home by SHS exposure in smoking and non-smoking families

	THS exposure at home		
	All (N=61810)	Smoking families (N=22558)	Non-smoking families (N=33344)
SHS exposure	%	%	%
At home			
From inside the home or neighbours			
None	4.6	17.3	1.6
Any	41.2	48.8	17.0
From inside the home			
None	7.2	23.3	3.2
Any	48.4	48.4	33.8
From neighbours			
None	10.7	27.8	1.8
Any	47.0	71.9	16.7
Outside home			
None	5.7	17.6	1.3
Any	25.9	47.8	6.3

Percentages were weighted by age, sex and grade.

Table 4. Adjusted odds ratios (ORs) of respiratory symptoms for SHS exposure anywhere and THS exposure at home in never smoking students (N=50762)

Exposure (days/week)	%	Respiratory symptoms (%)	Crude OR (95% CI)	Adjusted OR[a] (95% CI)	*P* for trend
At home					
SHS from inside the home					0.004
0	81.2	11.0	1	1	
1-4	10.1	13.7	1.21 (1.11-1.32)***	1.09 (1.00-1.19)*	
5-7	8.7	14.8	1.39 (1.27-1.52)***	1.14 (1.03-1.26)**	
Any	18.8	14.2	1.29 (1.21-1.38)***	1.13 (1.05-1.21)**	
SHS from neighbours					<0.001
0	85.0	11.2	1	1	
1-4	12.1	13.4	1.23 (1.14-1.33)***	1.14 (1.05-1.24)**	
5-7	2.9	17.2	1.74 (1.52-1.99)***	1.44 (1.26-1.63)***	
Any	15.0	14.2	1.33 (1.24-1.42)***	1.23 (1.14-1.32)***	
THS					<0.001
0	86.6	11.0	1	1	
1-4	10.1	14.5	1.31 (1.20-1.42)***	1.19 (1.07-1.32)**	
5-7	3.3	17.7	1.71 (1.51-1.93)***	1.29 (1.11-1.50)**	
Any	13.4	15.3	1.41 (1.31-1.51)***	1.22 (1.12-1.34)***	
Outside home					0.001
0	46.9	11.2	1	1	
1-4	38.6	11.1	1.01 (0.95-1.07)	0.95 (0.89-1.02)	
5-7	14.6	14.2	1.37 (1.27-1.48)***	1.22 (1.12-1.33)***	
Any	53.1	12.0	1.11 (1.05-1.17)***	1.02 (0.96-1.09)	
Number of exposure sources	%	Respiratory symptoms (%)	Crude OR (95% CI)	Adjusted OR[b] (95% CI)	*P* for trend
0	39.2	10.9	1	1	<0.001
1	34.5	10.7	1.02 (0.96-1.09)	1.04 (0.97-1.11)	
2	16.5	11.8	1.13 (1.04-1.22)**	1.12 (1.03-1.22)**	
3	7.1	15.1	1.42 (1.28-1.57)***	1.40 (1.26-1.56)***	
4	2.8	20.5	2.02 (1.77-2.31)***	1.99 (1.74-2.28)***	

Percentages were weighted by age, sex and grade

[a]Adjusted OR: Different exposure sources were adjusted mutually and for age, sex, housing type, highest parental education and school clustering effect

[b]Adjusted OR: Adjusted for age, sex, housing type, highest parental education, and school clustering effect

*P<0.05, **P<0.01, ***P<0.001