

Household incense burning and children's respiratory health: A cohort study in Hong Kong

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Abstract

Background: Incense burning is an important source of indoor air pollution in many Asian regions. We investigated the associations between household incense burning and lung function, lung function growth and respiratory diseases and symptoms in primary school children in Hong Kong.

Methods: A total of 4041 children (mean age: 9.1 years) were recruited from 27 primary schools in Hong Kong. Information on incense burning and medical history of respiratory diseases and symptoms was collected by questionnaire. Spirometry tests were performed to measure the children's lung function. A follow-up study was carried out after 1-year interval. Linear and logistic regression models were used to investigate the associations between incense burning, lung function, and lung function growth, and respiratory diseases and symptoms, respectively.

Results: At baseline, incense burning was associated with 48.6 mL/min [95% confidence interval (CI): -96.7, -0.5] lower maximum mid-expiratory flow (MMEF) in boys. In follow-up, incense burning was associated with reduced peak expiratory flow (PEF) growth in all participants. We also found that incense burning was associated with increased prevalence of bronchitis [odds ratio (OR) = 1.39, 95%CI: 1.11, 1.72] and bronchiolitis (OR = 1.72, 95%CI: 1.14, 2.56). Incense burning was also associated with higher prevalence of pneumonia (OR = 2.79, 95%CI: 1.10, 6.87) and wheezing (OR = 1.49, 95%CI: 1.08, 2.05) in boys, but not in girls.

Conclusions: We found that incense burning may adversely affect children's respiratory health. Further studies are warranted to elucidate the underlying mechanisms.

KEYWORDS

children, Incense burning, lung function, respiratory diseases and symptoms

1 | INTRODUCTION

Incense burning is a common practice in Asia-Pacific and Middle East regions. Incense is used for aesthetic reasons and in ceremonies such as worship rituals for gods and ancestors. However, burning incense

can generate large amounts of particles, aerosols, gaseous pollutants (eg, nitrogen dioxide and sulfur dioxide), and various volatile organic compounds (eg, formaldehyde, polycyclic aromatic hydrocarbons, benzene, etc.),¹⁻³ all of which have great potential to cause adverse health effects.

Animal experiments have linked incense burning with damages to pneumocytes.^{4,5} An *in vitro* experiment also showed that incense smoke could induce cytotoxicity and genotoxicity.⁶ Some epidemiological studies have also investigated the health effects of incense burning, mainly on the respiratory system, but the results are inconsistent.^{7–17} Most such studies have focused on children because children are more vulnerable to the adverse effects of air pollutants than adults. Children's developing lungs are highly susceptible to damage after exposure to environmental toxicants,¹⁸ and children have greater exposure than adults because of their higher ventilation rates.¹⁸ Among the studies in children, some have found incense burning to be associated with increased risk of respiratory diseases and symptoms,^{8,9,13,16} while others have found no significant association.^{7,11,14} Two studies even found that incense burning was associated with reduced risks of asthma and respiratory symptoms.^{10,15} These studies generally investigated the health effects of incense burning on respiratory diseases and symptoms, but none of them investigated lung function, which is an important objective indicator of respiratory health. Therefore, we investigated the associations between incense burning and lung function, and incense burning and respiratory diseases and symptoms in school children in Hong Kong.

2 | MATERIALS AND METHODS

2.1 | Study participants

Study participants were from a prospective cohort study of school children in Hong Kong, which aimed to investigate the respiratory health effects of indoor air pollution. Details of the study have been documented elsewhere.^{19,20} Briefly, 27 primary schools were randomly selected from four regions in Hong Kong (Hong Kong/outlying islands, Kowloon, New Territories East and New Territories West). A total of 4676 students were recruited at baseline. Participants underwent a spirometry test and anthropometric measurements. Meanwhile, their parents/guardians were required to complete a self-administered questionnaire. The baseline survey was finished in 2012 and 2013 and then a follow-up survey using the same procedures was carried out in 2013 and 2014 with an interval of around 1 year. In the present study, we conducted cross-sectional data analyses (using baseline data only) to investigate the associations between incense burning and lung function and respiratory diseases and symptoms. We also conducted longitudinal data-analyses (using both baseline and follow-up data) to investigate the associations between incense burning and lung function growth. The parents/guardians gave written informed consent before their children's participation. The study protocol was approved by the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee.

2.2 | Data collection

Height and weight were measured with participants wearing light cloth and no shoes. Spirometry tests were performed by trained research

assistants according to the standards of the American Thoracic Society (ATS)/European Respiratory Society (ERS) Task Force.²¹ Calibration was also conducted according to the standards. For each participant, forced vital capacity (FVC), forced expiratory volume in 1 s (FEV₁), peak expiratory flow (PEF), and maximum mid-expiratory flow (MMEF) were measured. Each student had to perform at least three satisfactory blows to pass the test. Brief rest periods were given between trials. Spirometry tests were conducted in the morning and mainly in cool season (September to February). For each school, follow-up tests were carried out in the same month of the following year to ensure an approximately equal follow-up period (around 1 year) for all participants.

A self-administered questionnaire completed by the participants' parents/guardians was used to collect information on socio-demographics, lifestyle, disease history, and household environment. The information on household incense burning was collected using the question "Do you burn incense in your home?" We used this question because previous studies have suggested that families in Hong Kong generally either burn incense regularly or not at all.⁷ For those who burn incense, it is usually done daily or on religious festivals. Questions mainly adopted from the survey tools of the International Study of Asthma and Allergies in Childhood (ISAAC), ATS, and the European Community Respiratory Health Survey^{19,22} were used to collect information on self-reported respiratory symptoms (including wheezing, dry cough, and phlegm) and physician-diagnosed respiratory diseases (including asthma, allergic rhinitis, sinusitis, bronchitis, bronchiolitis, and pneumonia).

2.3 | Statistical analysis

We performed a complete cases analysis and participants with missing information were excluded. A total of 4041 participants were included in the baseline analysis of incense burning and respiratory diseases/symptoms. Among them, 3811 children successfully performed the spirometry test and were included in baseline analysis of incense burning and lung function. Among these participants, 2826 with follow-up data were included in the longitudinal analysis of incense burning and lung function growth. Annual growth in FVC, FEV₁, PEF, and MMEF was calculated.

Linear regression models were used to investigate the associations between incense burning and lung function and lung function growth with adjustment for age (as a continuous variable), sex (boy or girl), height (as a continuous variable), weight (as a continuous variable), paternal educational level (primary school or lower, secondary school, or tertiary school or higher), leisure-time physical activity (at least once a week: yes or no), breastfeeding (breastfeeding ≥ 6 months according to the World Health Organization:²³ yes or no), premature birth (yes or no), medical history of asthma (yes or no), and household environmental factors including passive smoking (yes or no), keeping a pet/pets (yes or no), keeping a plant/plants (yes or no), recent renovation (yes or no), recent purchase of furniture (yes or no), ventilation (frequently opening windows: yes or no), and type of fuels used for cooking (fossil fuels [eg, coal and gas] or electricity). Logistic regression models were

used to examine the associations between incense burning and respiratory diseases/symptoms at baseline with adjustment for the same covariates as in the linear regression analysis, except that medical history of asthma was not included. To examine the patterns in different sex groups, sex-specific analyses were carried out separately for boys and girls.

All statistical analyses were performed using R 3.2.5 (R Core Team, Vienna, Austria). A two-tailed *P*-value of <0.05 was considered statistically significant.

3 | RESULTS

Baseline general characteristics of the study participants are presented in Table 1. The average age was 9.1 (SD: 1.0) years and there were slightly more boys than girls. A total of 808 (20.0%) participants reported exposure to household incense burning. The general characteristics were generally comparable among boys and girls except that boys were more physically active. For respiratory diseases/symptoms, the top three reported diseases/symptoms were allergic rhinitis (41.0%), dry cough (27.2%), and phlegm (12.4%). Most respiratory diseases/symptoms were more prevalent in boys than girls. For baseline lung function, boys had higher FVC, FEV₁, and PEF than girls and the sex difference for MMEF was not statistically significant (Table 2).

Table 3 shows the results of linear regression analysis for incense burning and lung function at baseline. Incense burning was associated with lower lung function levels but the negative association only reached statistical significance for MMEF in boys. Compared with boys not exposed to household incense burning, those exposed had 48.6 ml/min (95% confidence interval (CI): -96.7, -0.5) lower MMEF. Incense burning was also negatively associated with annual lung function growth, and the association was statistically significant for PEF in all subjects, but not for the other three parameters (Table 4). In sex-stratified analysis, none of the negative associations between incense burning and lung function growth were statistically significant (Table 4).

Exposure to household incense burning was associated with increased prevalence of bronchitis, bronchiolitis, pneumonia, and wheezing in boys. However, no significant associations between incense burning and respiratory diseases/symptoms were found for girls. When combining both sexes, incense burning was associated with increased risks of bronchitis and bronchiolitis. The odd ratios (ORs) were 1.39 (95%CI: 1.11, 1.72) and 1.72 (95%CI: 1.14, 2.56), respectively, (Table 5).

4 | DISCUSSION

To our knowledge, this is the first epidemiological study which simultaneously investigated the health effects of exposure to household incense burning on lung function, lung function growth and respiratory diseases and symptoms in children. We found that incense burning was associated with lower MMEF in boys and reduced

PEF growth in all of our study participants. We also found that incense burning was associated with increased risks of bronchitis and bronchiolitis. For boys, incense burning was also associated with increased risks of pneumonia and wheezing.

Our findings on the adverse effects of incense burning on lung function and lung function growth in children are novel. FVC indicates the maximum volume of air exhaled from the lungs in a forced breath, FEV₁ mainly reflects the mechanical properties of large airway, while PEF and MMEF are more indicative of peripheral small airway functions.²⁴ Thus, our findings suggest that small airways might be more sensitive to the adverse effects from incense burning. More research is required to confirm our findings and to elucidate their possible mechanisms.

Previous epidemiological studies generally focused on the health effects of incense burning on respiratory diseases and symptoms in children with inconsistent results. Two studies in Taiwan found that incense burning was associated with increased reporting of respiratory diseases and symptoms such as coughing in children.^{8,9} Another Taiwan study of 3764 children reported that incense burning was associated with increased risks of asthma and wheezing.¹³ A study of 2203 Hong Kong children found that exposure to incense burning was associated with increased risk of chronic cough in boys but not in girls.¹⁶ In contrast, Koo et al⁷ found no significant association between incense burning and respiratory diseases and symptoms in 346 children in Hong Kong. An Omani study reported no significant association between incense burning and prevalence of asthma, and found that incense burning was only a triggering factor of wheezing in asthmatic children.¹¹ A study in the United Arab Emirates found that incense burning was associated with neurological symptoms such as headaches, difficulty concentrating, and forgetfulness while no consistent pattern was detected between incense burning and respiratory symptoms.¹⁴ Two studies in Taiwan and China even reported protective effects of incense burning on asthma and hay fever.^{10,15} More studies are needed to address the inconsistency of current evidence.

Our findings on the adverse respiratory health effects of incense burning were more evident in boys than in girls. For example, the negative association between incense burning and MMEF was only significant in boys but not in girls. The associations between incense burning and bronchitis, bronchiolitis, pneumonia, and wheezing were also observed only in boy. Together, these findings suggest that boys might be more vulnerable to the adverse effects of incense burning than girls. The possible reasons for this are unknown. One potential explanation is that in the present study, boys generally had poorer respiratory health than girls, as more respiratory diseases and symptoms were reported in boys. Therefore, boys might be more sensitive to the adverse effects of incense burning because of a more unhealthy status. There is limited evidence from previous studies on the sex differences of the effects of incense burning on children's respiratory health and more studies are needed to better address this issue.

The biological mechanisms by which incense burning induces adverse respiratory health effects remain unclear. Experiments have

TABLE 1 General characteristics of study participants

Characteristics	Boys (N = 2063)	Girls (N = 1978)	P for comparison	All (N = 4041)
Age (year)	9.1 (1.0)	9.1 (1.0)	0.80	9.1 (1.0)
Height (cm)	134.3 (8.2)	133.8 (8.9)	0.06	134.0 (8.6)
Weight (kg)	32.5 (10.3)	30.6 (8.9)	<0.001	31.6 (9.7)
Paternal educational level			0.96	
Illiterate or primary school	190 (9.2%)	186 (9.4%)		376 (9.3%)
Secondary school	1396 (67.7%)	1330 (67.2%)		2726 (67.5%)
Tertiary school or above	477 (23.1%)	462 (23.4%)		939 (23.2%)
Breastfeeding	511 (24.8%)	472 (23.9%)	0.51	983 (24.3%)
Premature birth	160 (7.8%)	147 (7.4%)	0.72	307 (7.6%)
Physical activity (at least once a week)	1584 (76.7%)	1414 (71.5%)	<0.001	2997 (74.2%)
Household environment				
Incense burning	429 (20.8%)	379 (19.2%)	0.21	808 (20.0%)
Keeping a pet	244 (11.8%)	255 (12.9%)	0.32	499 (12.3%)
Keeping plants	1048 (50.8%)	1027 (51.9%)	0.49	2075 (51.3%)
Recent renovation	311 (15.1%)	258 (13.0%)	0.06	569 (14.1%)
Newly purchased furniture	320 (15.5%)	326 (16.5%)	0.42	646 (16.0%)
Ventilation (windows frequently opened)	1958 (94.9%)	1860 (94.0%)	0.24	3818 (94.5%)
Passive smoking	483 (23.4%)	456 (23.1%)	0.79	939 (23.2%)
Cooking fuels (fossil fuels)	1797 (87.1%)	1681 (85.0%)	0.13	3478 (86.1%)
Respiratory disease/symptom				
Asthma	91 (4.4%)	56 (2.8%)	0.007	147 (3.6%)
Allergic rhinitis	960 (45.5%)	696 (35.2%)	<0.001	1656 (41.0%)
Sinusitis	77 (3.7%)	38 (1.9%)	0.001	115 (2.8%)
Bronchitis	301 (14.6%)	226 (11.4%)	0.003	527 (13.0%)
Bronchiolitis	72 (3.5%)	51 (2.6%)	0.10	123 (3.0%)
Pneumonia	21 (1.0%)	21 (1.1%)	0.99	42 (1.0%)
Wheezing	234 (11.3%)	165 (8.3%)	0.001	399 (9.9%)
Dry cough	592 (28.7%)	506 (25.6%)	0.04	1098 (27.2%)
Phlegm	251 (12.2%)	250 (12.6%)	0.77	501 (12.4%)

Data are presented as mean (SD) for continuous variables and number (percentage) for categorical variables.

shown that exposure to incense smoke could lead to structural changes in rats' pulmonary alveolar cells.^{4,5} However, incense smoke is a complex mixture of particles, aerosols, gaseous pollutants, and various organic compounds. Therefore, it is difficult to exclusively investigate the health effects of a certain component of the incense smoke. Studies on the

health effects on different components of particulate matter, which is also a complex air pollutant, may have provided some insights,²⁵ and similar studies are expected for the assessment of incense smoke.

The present study has several strengths. First, this is the first study that investigated the associations between incense burning and lung

TABLE 2 Baseline lung function levels of study participants

Parameters	Boys (N = 1964)	Girls (N = 1847)	P for comparison	All (N = 3811)
FVC (mL)	1950.5 (358.2)	1810.5 (353.7)	<0.001	1882.6 (362.8)
FEV1 (mL)	1678.6 (312.1)	1587.3 (319.4)	<0.001	1634.3 (318.9)
PEF (mL/min)	3764.6 (755.4)	3636.8 (793.0)	<0.001	3702.6 (776.4)
MMEF (mL/min)	1873.3 (500.8)	1870.9 (521.4)	0.89	1872.2 (510.8)

Data are presented as mean (SD).

FEV1, forced expiratory volume in one second; FVC, forced vital capacity; MMEF, maximum mid-expiratory flow; PEF, peak expiratory flow.

TABLE 3 Associations between household incense burning and lung function in Hong Kong children

Lung function parameter	Boys (N = 1964)		Girls (N = 1847)		All (N = 3811)	
	Coef (95%CI)	P	Coef (95%CI)	P	Coef (95%CI)	P
FVC (mL)	-2.2 (-29.3, 24.8)	0.87	-15.3 (-42.5, 11.9)	0.27	-7.7 (-26.9, 11.4)	0.43
FEV ₁ (mL)	-10.1 (-33.9, 13.6)	0.40	-12.2 (-36.8, 12.3)	0.33	-10.2 (-27.2, 6.8)	0.24
PEF (mL/min)	-54.6 (-123.6, 14.4)	0.12	-29.0 (-102.2, 44.1)	0.44	-39.9 (-90.0, 10.1)	0.12
MMEF (mL/min)	-48.6 (-96.7, -0.5)	0.04	-9.8 (-60.8, 41.2)	0.71	-28.6 (-63.5, 6.4)	0.11

Results were adjusted for age, sex (not in sex-specific analysis), height, weight, paternal educational level, leisure-time physical activity, breastfeeding, premature birth, passive smoking, keeping a pet, keeping a plant, recent renovation, recent purchase of furniture, ventilation and cooking fuels. CI, confidence interval; FEV₁, forced expiratory volume in one second; FVC, forced vital capacity; MMEF, maximum mid-expiratory flow; PEF, peak expiratory flow.

TABLE 4 Associations between household incense burning and lung function growth in Hong Kong children

Lung function parameter	Boys (N = 1418)		Girls (N = 1408)		All (N = 2826)	
	Coef (95%CI)	P	Coef (95%CI)	P	Coef (95%CI)	P
FVC (mL)	5.9 (-17.5, 29.3)	0.62	-20.7 (-42.9, 1.5)	0.07	-6.8 (-22.9, 9.2)	0.40
FEV ₁ (mL)	8.8 (-15.3, 33.0)	0.47	-9.5 (-32.1, 13.1)	0.41	-0.01 (-16.5, 16.5)	0.99
PEF (mL/min)	-69.2 (-149.1, 10.8)	0.09	-66.6 (-147.4, 14.2)	0.11	-64.8 (-121.3, -8.2)	0.02
MMEF (mL/min)	-12.8 (-68.4, 42.8)	0.65	0.01 (-58.8, 58.9)	0.99	-6.6 (-47.0, 33.8)	0.75

Results were adjusted for age, sex (not in sex-specific analysis), height, weight, paternal educational level, leisure-time physical activity, breastfeeding, premature birth, passive smoking, keeping a pet, keeping a plant, recent renovation, recent purchase of furniture, ventilation and cooking fuels. CI, confidence interval; FEV₁, forced expiratory volume in one second; FVC, forced vital capacity; MMEF, maximum mid-expiratory flow; PEF, peak expiratory flow.

function and lung function growth in children. Our study provides some evidence of the adverse effects of incense burning on children's lung function and lung function development. Second, we used a cohort design, which enabled us to perform a longitudinal analysis on the associations between incense burning and lung function growth. Third, we took into consideration a wide range of potential confounders, which enabled us to better characterize the associations between incense burning and children's respiratory health.

Our study also has some limitations. Information on incense burning and most other covariates was collected via questionnaire, and our results are therefore subjective to participants' recall bias. Furthermore, information on the dose of the incense burned in households was not available, which limited our ability to examine the dose-response relationship. An additional limitation is that information on type of the incense burned was not available. A previous study in Taiwan suggested that the emission characteristics and health risk potential, particularly allergenic potential, of incense smoke varied for different types of

TABLE 5 Associations between household incense burning and respiratory diseases/symptoms in Hong Kong children

Respiratory diseases/symptoms	Boys (N = 2063)		Girls (N = 1978)		All (N = 4041)	
	OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
Asthma	1.38 (0.84, 2.21)	0.19	0.87 (0.42, 1.66)	0.68	1.19 (0.79, 1.74)	0.39
Allergic rhinitis	1.09 (0.88, 1.36)	0.44	1.25 (0.99, 1.59)	0.06	1.17 (0.99, 1.37)	0.06
Sinusitis	0.77 (0.40, 1.39)	0.41	1.24 (0.54, 2.59)	0.59	0.92 (0.56, 1.46)	0.73
Bronchitis	1.46 (1.09, 1.94)	0.01	1.32 (0.93, 1.84)	0.12	1.39 (1.11, 1.72)	0.003
Bronchiolitis	1.94 (1.13, 3.25)	0.01	1.39 (0.70, 2.60)	0.33	1.72 (1.14, 2.56)	0.01
Pneumonia	2.79 (1.10, 6.87)	0.03	0.66 (0.15, 2.02)	0.52	1.54 (0.75, 2.99)	0.22
Wheezing	1.49 (1.08, 2.05)	0.01	0.94 (0.61, 1.41)	0.78	1.25 (0.97, 1.60)	0.08
Dry cough	1.08 (0.84, 1.37)	0.56	1.01 (0.77, 1.31)	0.96	1.04 (0.87, 1.25)	0.63
Phlegm	1.28 (0.93, 1.75)	0.12	0.72 (0.49, 1.03)	0.08	1.00 (0.78, 1.26)	0.99

Results were adjusted for age, sex (not in sex-specific analysis), height, weight, paternal educational level, leisure-time physical activity, breastfeeding, premature birth, passive smoking, keeping a pet, keeping a plant, recent renovation, recent purchase of furniture, ventilation and cooking fuels. CI, confidence interval; OR, odds ratio.

incense sticks.²⁶ This may also contribute to the inconsistent findings from previous studies, especially those in different regions. Future studies may consider collecting this information to better characterize the health effects of incense burning.

In conclusion, we found that exposure to household incense burning was associated with impaired lung function, reduced lung function growth, and increased risks of respiratory diseases and symptoms in children. Our study provides suggestive evidence of the adverse respiratory effects of incense burning in children. Incense burning is a popular practice in many Asian regions and our findings have important public health implications. More studies are needed to confirm our findings and elucidate their underlying mechanisms.

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CONFLICTS OF INTEREST

None to declare.

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