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Adolescent lung function associated with incense burning and other environmental exposures at home

Y. C. Chen[1,2] | W. C. Ho[3] | Y. H. Yu[4,5]

[1]Department of Health Management, College of Medicine, I-Shou University, Yanchao District, Kaohsiung, Taiwan
[2]Bachelor's Degree Program for Indigenous Peoples in Long-term Care, I-Shou University, Yanchao District, Kaohsiung, Taiwan
[3]Department of Public Health, China Medical University, Taichung, Taiwan
[4]Department of Internal Medicine, Divisions of Pulmonary and Critical Care Medicine, China Medical University Hospital, Taichung, Taiwan
[5]School of Medicine, China Medical University, Taichung, Taiwan

Correspondence
Yi-Chun Chen, Department of Health Management, I-Shou University, Yanchao District, Kaohsiung, Taiwan.
Email: kimi@isu.edu.tw

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Abstract
Incense burning is a popular cultural and religious practice, but whether exposure to incense smoke has effects on lung function is unclear. We investigated association between lung function and incense burning exposure and other household exposures in adolescents who participated in a mass asthma-screening program. Information on asthmatic status and associated factors was obtained from parent-completed questionnaires and student-completed video questionnaires. Approximately 10% of students received lung function examinations. Valid lung function data of 5010 students aged 14-16 years in northern Taiwan were analyzed. Forced vital capacity (FVC) and forced expiratory flow in 1 second (FEV_1) were compared by incense burning status and other types of exposures for adolescents. Overall, 70.6% of students were exposed to incense smoke at home. The mean FVC and FEV_1 measures were lower among adolescents with daily exposure to incense burning than those without such exposure ($P<.05$). Sharing bedroom was also associated with decreased FVC and FEV_1. After controlling for confounding factors, multivariable linear regression analysis with generalized estimation equation showed that FVC was negatively associated with daily exposure to incense burning, sharing a bedroom, and living in a house adjacent to a traffic road. Such associations were also observed in FEV_1. Daily exposure to incense burning is associated with impaired adolescent lung function.

KEYWORDS
adolescent, home, household, incense burning, indoor air, lung function

1 | INTRODUCTION

People spend a major of their time indoors, especially children.[1,2] Household activities and environmental exposures at home are considered as risk factors of respiratory health for children.[3-5] In a Russian study of children, Spengler et al.[3] found that cough and phlegm were associated with crowding levels at home as well as traffic conditions outside the house, and the prevalence of asthma and respiratory symptoms increased with the presence of molds at home. Keall et al.[4] found that the dampness level of the house was associated with an increase in respiratory symptoms of children aged <7 years. The distances between home and major roadways have been found to be negatively associated with lung function for children.[5]

Incense burning is a common practice at home for culture and religious purposes in Taiwan as well as in most Asian countries. Incense burning also is common among Arabian or European populations for religious worship, masking odor, or pleasure.[6-8] However, incense burning has been considered as a noteworthy source of indoor air pollution. Fine and ultrafine particulate matter, volatile organic compounds, other gaseous compounds, and heavy metals are emitted from incense burning.[9-12] For children, exposure to incense smoke has been associated with increased respiratory symptoms. Wang et al.[13]

reported that the frequent burning of Chinese incense is associated with asthma in adolescents. Hsu et al. indicated that children exposed to incense burning and living in a damp house are at an increased risk of asthma or allergy, particularly for children with paternal history of asthma or allergy.[14] A community survey in Oman found that Arabian incense could worsen wheeze in 38% of asthmatics, but was not associated with the current asthma prevalence.[6]

Because children are growing, whether exposure to incense burning at home leads to a risk of damaging their lung function is important in public health. Therefore, in this study, we evaluated the lung functions for adolescents of 14-16 years of age who had participated in an asthma-screening program in junior high schools of northern Taiwan. These junior high school children may spend 8-10 hours at school and the rest of time at home and other places.[2] We examined whether the lung function of these adolescent was associated with exposure to incense burning at home along with other household environmental exposures.

Practical Implications

- Our findings suggest that daily exposure to incense smoke at home is a risk factor associated with a decline in the lung function. Adolescents may need to reduce the exposure to the fumes of burning incense.

2 | METHODS

2.1 | Study population and data collection

The asthma-screening program for adolescents was conducted from 1995 to 1997, and the details have been reported in previous studies.[15,16] The Research Ethics Committee of the College of Public Health, National Taiwan University, approved this study.[15] In brief, the study team invited all middle schools in Taiwan to participate in the screening survey with the approval of education authority. With parental consents and assistance from school teachers, nearly all children from 7th to 9th grades in Taiwan participated in the asthma-screening survey. Among the participants, approximately 10% students were randomly selected for lung function examinations. Considering the respiratory symptoms and smoking by children may affect their lung function. In this study, we here report the qualified and reliable lung function data for 5010 no-smoking adolescents with neither asthma nor doctor-diagnosed allergic rhinitis in northern Taiwan.

The parent of each participating student completed the Chinese versions of the New England core questionnaire and returned it to the study team with the assistance from teachers.[17] Students self-completed the International Study of Asthma and Allergies in Childhood (ISAAC) video questionnaires in their classroom after viewing the video with the assistance of trained experts.[18] The parental questionnaire provided information on the student's attributes and health status (birthday, sex, and ever been diagnosed by physician having allergic rhinitis [yes/no]), the habits of exercise (always/seldom/no), and smoking (yes/no). The questionnaire also asked about environmental exposures in households, including incense burning at home (daily/twice monthly/no), families smoking at home (yes/no), student sharing a bedroom with other family members (yes/no), house or building adjacent to traffic road (yes/no), mold in house (yes/no), aviculture on the patio or roof (yes/no), and having pets (yes/no). Exercise was classified as "always" for students who exercise at least three times every week, "seldom" as exercising one or two times every week, and "no" for students who never exercise. Parents also provided the information whether students had ever been diagnosed by physician to have asthma (yes/no) in the past 12 months. If this answer was "yes," students were classified as doctor-diagnosed asthma. Students who had affirmed episodes and/or symptoms of asthma shown in the video were also classified as being asthmatic.

2.2 | Lung function test

Lung function tests were performed at schools using a calibrated, computerized spirometer (Model 2130; Sensormedics, Yorba Linda, CA, USA). Each student repeated measurements for three to eight times until an optimal result appeared. An experienced technician conducted the tests according to the American Thoracic Society criteria.[19] Before measuring lung function, students were measured for height and weight to calculate the body mass index (BMI) value. The lung function data used in this study included the forced vital capacity (FVC) and forced expiratory flow in 1 second (FEV_1). No predictive lung function model has been developed for adolescents in Taiwan. We converted FVC and FEV_1 into sex-, age-, height-, and weight-specific *z*-score based on the predictive values of randomly selected 1000 non-smoking students with neither asthma nor allergic rhinitis. The predictive equations are described below.

FVC (L)

Boy: $0.060 \times \text{age (year)} + 0.042 \times \text{height (cm)} + 0.017 \times \text{weight (kg)} - 5.041$

Girl: $0.025 \times \text{height (cm)} + 0.017 \times \text{weight (kg)} - 1.919$

FEV_1 (L)

Boy: $0.080 \times \text{age (year)} + 0.043 \times \text{height (cm)} + 0.011 \times \text{weight (kg)} - 5.560$

Girl: $0.048 \times \text{age (year)} + 0.028 \times \text{height (cm)} + 0.010 \times \text{weight (kg)} - 2.889$

2.3 | Statistical analysis

The attributes and lung functions of the students, habits regarding incense burning at home, and environmental exposures from the students' households were analyzed using univariate analysis first. Considering that lung function is significantly associated with sex,[17] we conducted sex-specific analyses to examine the association between the mean levels of lung function (FVC and FEV_1) in relation to environmental exposures from students' households using Student's *t* test or one-way ANOVA.

We assumed that students living in the same residential district were exposed to similar outdoor air pollutant levels. In this study, the participating students were categorized according to their residential district, and students in the same district were assumed to be exposed to similar levels of air pollutants. The multivariable linear regression analysis with generalized estimation equation (GEE) was then used to evaluate *z*-score of FVC and FEV_1, separately, in association with incense burning at home, family smoking at home, students sharing a bedroom, house or building located adjacent to a traffic road, mold in home, aviculture on the patio or roof, and having pets. Regression coefficients (β) and standard errors (SE) were measured, including residential district as a random effect variable. The model was adjusted for school, temperature at time of lung function measurements, age, sex, exercise, BMI, and the interactions between sex and BMI, sex and mold in house, sex and aviculture on the patio or roof, and sex and having pets. In the multivariable linear regression analysis with GEE, no incense burning, no family smoking at home, house not adjacent to traffic, no mold in house, no aviculture at home, and not having pets were used as reference conditions. All data were analyzed using IBM SPSS Statistics version 18 software (IBM Corp., Armonk, NY, USA), and the statistical significance level (α) was set at 0.05.

3 | RESULTS

3.1 | Personal attributes and environmental exposures at home

Table 1 shows personal attributes, lung function, and environmental exposures at students' households for the 5010 participating students. The mean FVC was greater in boys than in girls (3.70±0.58 L vs 2.77±0.40 L), and so was for the mean FEV_1 (3.44±0.25 L vs 2.62±0.38 L, respectively). In all, 47.4% of students shared a bedroom with somebody. Approximately 71% of students were potentially exposed to incense burning at home for religious worship. A proportion of 37.4% of students lived in houses or buildings adjacent to traffic road, and about 12% students' households had aviculture on the patio or roof.

TABLE 1 Personal attributes, lung function, and the environmental exposures at students' household of participating students

Personal attributes	Mean (SD)/n[a] (%)	Environmental exposures at household	n[a] (%)
Age, years	14.48 (0.57)	Incense burning	
Sex		Daily	2311 (46.1)
Boy	2485 (49.6)	Twice monthly	1228 (24.5)
Girl	2525 (50.4)	No	1446 (29.4)
BMI, kg/m^2	21.01 (3.50)	Family smoking at home	
Exercise[b]		Yes	2681 (53.8)
Always	1963 (39.2)	No	2301 (46.2)
seldom	2333 (46.6)	Sharing bedroom	
No	708 (14.1)	Yes	2373 (47.4)
Lung function		No	2614 (52.2)
Boys		House or building adjacent to	
FVC, L	3.70 (0.58)	Traffic road	1874 (37.4)
FEV_1, L	3.44 (0.54)	No	3136 (62.6)
Girls		Mold in house	
FVC, L	2.77 (0.40)	Yes	1539 (30.8)
FEV_1, L	2.62 (0.38)	No	3452 (69.2)
		Aviculture on the patio or roof	
		Yes	611 (12.2)
		No	4350 (86.8)
		Having pets	
		Yes	1338 (26.7)
		No	3657 (73.0)

SD, standard deviation; BMI, body mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s.
[a]Numbers of subjects have excluded missing values.
[b]Always: at least three times a week; Seldom: less than three times a week; No: never exercising.

3.2 | Lung function associated with incense burning and exposures at home

Table 2 shows sex-specific lung function associated with environmental exposures at students' households. Students' lung function measures of both FVC and FEV_1 were lower in cases with incense burning in their households. Compared to students without incense exposure, the mean FVC was 0.07 L less in boys and 0.05 L less in girls with daily exposures to incense (both $P<.05$). The corresponding differences in FEV_1 were 0.06 L in boys and 0.06 L in girls, which were not statistically significant for boys. Sharing the bedroom was also associated with reduced FVC and FEV_1 for both boys and girls. Living near a traffic road was associated with reduced lung function for girls, but not for boys. Family aviculture hobby was associated with reduced lung function for boys, but not for girls. For all students, family smoking at home was associated with decreased FEV_1 and mold in the house was associated with decreased FVC. However, keeping pets had no significant association with lung function in this dataset.

Table 3 shows the results for lung function associated with incense burning and with other environmental exposures in households, as analyzed by multivariable linear regression analysis with GEE controlling for school, temperature, age, sex, exercise, BMI, and the interactions between sex and BMI, sex and mold in house, sex and aviculture on the patio or roof, and sex and having pets. Compared to students living in households without incense burning, *z*-score of FVC and FEV_1 significantly decreased among students with daily exposure to incense burning (β=−.107 (SE=.033) for *z*-score of FVC and β=−.144 (SE=.041) for *z*-score of FEV_1, $P<.05$). However, twice-monthly incense burning at home was not associated with decreasing adolescent lung function. Sharing a bedroom with family members was negatively associated

TABLE 2 Sex-specific lung function associated with the environmental exposures at students' households of participating students

	Boys			Girls			Total		
		FVC, L	FEV_1, L		FVC, L	FEV_1, L		FVC, L	FEV_1, L
Variables	n	Mean (SD)	Mean (SD)	n	Mean (SD)	Mean (SD)	n	Mean (SD)	Mean (SD)
Incense burning									
Daily	1141	3.67 (0.58)*	3.42 (0.54)	1170	2.75 (0.40)*	2.59 (0.38)*	2311	3.20 (0.68)*	3.00 (0.62)*
Twice monthly	633	3.72 (0.58)	3.45 (0.52)	595	2.77 (0.39)	2.62 (0.38)	1228	3.26 (0.68)	3.05 (0.62)
No	696	3.74 (0.59)	3.48 (0.53)	750	2.80 (0.40)	2.65 (0.38)	1446	3.26 (0.69)	3.05 (0.62)
Family smoking at home									
Yes	1295	3.70 (0.58)	3.44 (0.53)	1386	2.76 (0.39)	2.61 (0.38)	2681	3.22 (0.68)	3.01 (0.62)*
No	1175	3.71 (0.59)	3.45 (0.54)	1126	2.78 (0.40)	2.63 (0.39)	2301	3.25 (0.69)	3.05 (0.62)
Sharing bedroom									
Yes	1061	3.64 (0.58)*	3.39 (0.52)*	1312	2.75 (0.39)*	2.60 (0.37)*	2373	3.15 (0.65)*	2.95 (0.59)*
No	1407	3.75 (0.59)	3.48 (0.55)	1207	2.79 (0.40)	2.63 (0.39)	2614	3.31 (0.70)	3.09 (0.64)
House or building adjacent to									
Traffic road	915	3.68 (0.57)	3.42 (0.52)	959	2.74 (0.40)*	2.59 (0.38)*	1874	3.20 (0.68)*	2.99 (0.62)*
No	1570	3.72 (0.59)	3.46 (0.54)	1566	2.79 (0.39)	2.63 (0.38)	3136	3.25 (0.68)	3.05 (0.62)
Mold in house									
Yes	719	3.71 (0.59)	3.46 (0.55)	820	2.76 (0.40)	2.61 (0.38)	1539	3.20 (0.69)*	3.00 (0.63)
No	1752	3.70 (0.58)	3.44 (0.53)	1700	2.78 (0.39)	2.62 (0.38)	3452	3.25 (0.68)	3.04 (0.62)
Aviculture on the patio or roof									
Yes	284	3.62 (0.57)*	3.37 (0.54)*	327	2.77 (0.39)	2.60 (0.38)	611	3.20 (0.64)*	2.96 (0.60)*
No	2168	3.71 (0.58)	3.45 (0.53)	2182	2.77 (0.40)	2.62 (0.38)	4350	3.24 (0.69)	3.03 (0.62)
Having pets									
Yes	606	3.70 (0.59)	3.44 (0.55)	732	2.79 (0.39)	2.63 (0.38)	1338	3.20 (0.67)	3.00 (0.61)
No	1868	3.70 (0.58)	3.44 (0.53)	1789	2.76 (0.40)	2.61 (0.38)	3657	3.24 (0.69)	3.04 (0.62)

FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; SD, standard deviation.
*P<.05 by Student's t test or one-way ANOVA.

with z-score of FVC (β=−.110 (SE=.024), P<.001) and z-score of FEV_1 (β=−.105 (SE=.032), P=.001). Students living near to traffic road have lower z-score of FVC (β=−.083 (SE=.027), P=.002) and z-score of FEV_1 (β=−.137 (SE=.034), P<.001) than in locations without nearby traffic. Having pets at home were positively associated with z-score of FVC and FEV_1 (P<.05). There were no associations between adolescent lung function and family smoking at home, mold in house, as well as aviculture on the patio or roof.

4 | DISCUSSION

This study used data of mass screening for asthma in adolescents without history of smoking, asthma, and/or allergic rhinitis to explore lung function associated with incense burning at home along with other household environmental exposures. Over 70% of participants reported exposure to incense burning at home and those with daily exposure had lower FVC and FEV_1. However, exposure to incense burning for only twice monthly was not associated with a decline of FVC and FEV_1. The multivariable linear regression analysis showed that the association with incense smoke exposure was independent of other tested parameters and exposure indicators.

The complex mixtures emitted from incense burning include fine and ultrafine particulate matter, carbon monoxide, carbon dioxide, nitrogen oxides, and volatile organic compounds, heavy metals, and other gaseous compounds.[19-22] Increased indoor levels of carbon dioxide and total volatile organic compounds elevated the oxidative stress.[21] Exposure to these chemicals may impair the lung defense and lead to declined lung function. Lui et al.[22] used human alveolar epithelial A549 cells exposed to $PM_{2.5}$ emitted from incense burning. Major chemical components of $PM_{2.5}$ in the incense smoke included polycyclic aromatic hydrocarbons and some oxygenated polycyclic aromatic hydrocarbons, which may lead to inflammatory response.[22] Hussain et al.[23] found that long-term exposure to incense fumes increased the oxidative stress in the lung and liver tissues of male Wister Albino rats. In another animal study, Alarifi et al.[24] observed that the alveolar cells of rats exposed to Arabian incense became necrotic, indicating the injury of the airways. Compared with church workers, Ho et al. have found that temple workers are at a greater risk of irritation in the throat and nose.[25] A large amount of incense is usually burned in the

TABLE 3 Multivariable linear regression analysis with generalized estimation equation[a] for lung function associated with incense burning and the selected environmental exposures at students' households

	Mean difference in *z*-FVC			Mean difference in *z*-FEV_1		
Variables	**β**	**SE**	***P*-value**	**β**	**SE**	***P*-value**
Incense burning						
Daily	−.107	.033	.001	−.144	.041	<.001
Twice monthly	−.035	.035	.312	−.016	.046	.724
No (as reference)						
Family smoking at home						
Yes	.024	.027	.371	.017	.029	.557
No (as reference)						
Sharing bedroom						
Yes	−.110	.024	<.001	−.105	.032	.001
No (as reference)						
House or building adjacent to						
Traffic road	−.083	.027	.002	−.137	.034	<.001
No (as reference)						
Mold in house						
Yes	−.027	.034	.420	.005	.035	.875
No (as reference)						
Aviculture on the patio or roof						
Yes	.007	.030	.820	.020	.0485	.678
No (as reference)						
Having pets						
Yes	.079	.032	.012	.088	.035	.012
No (as reference)						

z-FVC, *z*-score of forced vital capacity; *z*-FEV_1, *z*-score of forced expiratory volume in 1 s; β, regression coefficient; SE, standard error.
[a]Multivariable linear regression analysis with generalized estimation equation included district as a random effect variable and adjusted for school, temperature, age, sex, exercise, body mass index (BMI), and the interactions between sex and BMI, sex and mold in house, sex and aviculture on the patio or roof, and sex and having pets.

prayer practice of Buddhism/Taoism culture. Studies have associated incense burning with the risk of developing asthma and the smoke may aggravate wheezing in asthmatics.[6,13,14] Daily incense burning may contribute high levels of emitted pollutants to the indoor air leading to elevated oxidative stress, inducing an irritancy response, changing pulmonary structures, and decreased adolescents lung function.

In this study, the prevalence of students sharing bedroom with family members was 47.4% and this practice was associated with decreased FVC and FEV_1. The indoor concentration of carbon dioxide elevated with increasing crowding levels and associated with dry throat, tiredness, and dizziness.[26] The crowding levels at home were associated with cough and phlegm among children.[3] Cardoso et al.[27] found that children below 5 years of age sharing a bedroom had an increased risk of lower respiratory infection. Children sharing a bedroom may also have an increased chance of cross-infection, which could cause a decrease in lung function.

Traffic-related pollutants are associated with decreasing lung function among children. Our results also showed that adolescents living near to areas with traffic had lowered lung function, consistent with previous studies. Rice et al.[5] found an inverse association between the distances from home to major road and lung function among children. Cakmak et al.[28] found that increasing truck turning movement counts were negatively associated with FVC and increased the prevalence of respiratory symptoms for children among lower-income families.

Although only 12% of students' households had aviculture on the patio or roof, FVC and FEV_1 for boys were lower among these households than those without this practice. Such relationship was not observed among girls. In a survey for Latino poultry workers, Mirabelli et al.[29] found that mean FVC and FEV_1 values were lower among poultry workers, especially for men, than among a comparison population. Kearney et al.[30] also found that the values of lung function among poultry workers were smaller than predicted values. Martine et al.[31] analyzed the bioaerosol samples from a duck production facility and observed bacteria such as *Escherichia*, *Shigella*, *Staphylococcus* in deposited particles, with diameters below 1 μm, which may be inhaled into alveoli.

The unadjusted comparison in our data showed that family smoking at home was associated with reduced FEV_1 in children and mold in house was associated with reduced FVC. These relationships became in no significant in the multivariable analysis. It is not consistent with previous studies, which have associated impaired airway and declined lung function in children with family smoking and mold in house.[32-34] Children who participated in this study were all non-smoking adolescents with neither asthma nor allergic rhinitis. The religious incense burning is generally practiced before breakfast and/or supper in the living room or dining room in Taiwan. Children may have a greater exposure to the incense smoke than the secondary smoke at home. In general, the behavior of paternal smoking is cautious in some families. Therefore, the impacts on lung function from family smoking at home or mold in houses might be over-adjusted in the multivariable analysis.

It is interesting to note in our multivariable analysis that adolescents owning a pet at home have an increased lung function. This finding is consistent with some recent studies. Collin et al.[35] followed up a UK cohort of 8-year-old children and found that those who had owned pet rodents or birds were positively associated with FVC and FEV_1 values. Lowe et al.[36] found the ownership of dog and cat was not associated with decreased lung function in toddlers.

To the best of our knowledge, this study is one of the few to explore the association between adolescent lung function and exposure to incense burning at home. However, this study has some limitations. A cross-sectional design was used, which cannot establish causal relationships between studied lung function and risk factors. The concordance of responses of asthmatic status in questionnaires from students and their parents was perhaps not strong, but it might be a non-differential bias in this study. The effects of social status, diet, health status of adolescents, the cooking style, cleaning product usage, and dampness level at home were not considered as covariates in this study. Information bias from self-reported questionnaires may lead to an underestimate of the relationship between lung function and risk factors. Besides, as the included participants were between 14 and 16 years of age, we cannot extrapolate from our results to all ages of children. Additional studies are required to validate this concern.

5 | CONCLUSION

Our findings suggest that frequent exposure to incense burning at home is associated with the decline of lung function in adolescents. Lowered lung function also associated with sharing a bedroom with family members and living in houses adjacent to traffic. Children living in house with daily incense burning should use caution to avoid the exposure to the smoke of burning incense.

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