Home risk factors for childhood pneumonia in Nanjing, China

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Pneumonia is a major cause of childhood morbidity in China. Many studies of rural areas have found an association between pneumonia and air pollution from burning of bio-mass. The present study is of children living in urban, modern homes without burning of bio-mass. In order to investigate potential home risk factors associated with children's pneumonia, China Child Home Health (CCHH) questionnaires were randomly distributed to parents of 6461 children in 23 kindergartens in all 11 districts of Nanjing, covering urban, suburban, and industrial areas. The 4014 valid questionnaires (response rate 65.7%) were returned and have been analyzed. The lifetime incidence of pneumonia in Nanjing children 1–8 years old is 26.7%. The incidence of croup, asthma and frequent common colds was strongly associated with pneumonia, as was a history of allergies in the family, and persons other than parents (for example grandparents or nanny) taking care of the child. Several home environmental factors, namely, dampness, lack of ventilation, using coal or natural gas (electricity as reference) for cooking, new furniture, and "modern" floor and wall covering materials were also significantly associated with pneumonia. The indoor environment typical of modern apartments in China was a risk factor for pneumonia among children.

ventilation, dampness, life style, pneumonia

Childhood pneumonia is the world's leading causes of death among children [1–3], with about 800000 deaths annually of children <5 years of age [4,5]. Pneumonia is also the leading cause of death in children <5 years old in China [6] and one of the leading causes of death in adults in China [7]. The Chinese Ministry of Health reported that pneumonia mortality of infants was 21.86/100 k for children <1 year of age and 2.38/100 k for children 1–5 years old in 2009 [6]. Zhang [8] reviewed the literature on childhood pneumonia in China and found that the incidence of pneumonia for children <5 years old was 26.5% (95% CI: 26.3%–26.7%) south of the Yangtze River, and 8.4% (95% CI: 8.2%–8.7%) north of Yangtze River. Zhang [8] and Guan et al. [9] found no significant differences in childhood pneumonia incidence between the West and East of China. By comparison, the incidence of pneumonia and acute respiratory infections is quite low in developed countries [10]. It is reported that the incidence of childhood pneumonia is only 0.02% to 0.38% episodes per child-year among children <5 years old in Norway, USA, Finland, Scotland and UK [11–14], while it was reported that to be 6%–27% episodes per childe-year among children <5 years in China [9]. The same conclusions were found by Rudan et al. [3] that the incidence estimated to be 0.29 episodes per child-year in developing and 0.05 episodes per child-year in developed countries among children<5 years.

Indoor air pollution from burning unprocessed biomass and coal for cooking has been considered as a major risk

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factor for pneumonia in developing countries [15–17]. Children exposed to smoke from household biomass fuel have been shown to have a rate of acute lower respiratory infection (ALRI) twice that of unexposed children [16]. Zhou [18] compared pneumonia rates in rural and urban settings in Guangzhou and found that pneumonia rates in rural areas were more than four times higher than those in urban areas for children < 1 year of age, and more than six times higher for children <5 years of age. Thus, heavily polluted indoor air is a main cause of acute increased morbidity and mortality consequent to respiratory infections (ARI) [2,19]. Besides of air pollution, Rudan et al. [3] also found that malnutrition, low birth weight, non-exclusive breastfeeding, lack of measles immunization and crowding were risk factors for pneumonia.

China has developed rapidly in the last three decades. In Nanjing, people mainly live in apartments without burning bio-mass or coal. However, the existing literature indicates that the incidence of childhood pneumonia is much higher in cities in China than in developed countries [9,15]. The aim of this study was to characterize those indoor aspects of modern Chinese homes that are associated with childhood pneumonia especially to investigate the effect of pollutants generated by modern Chinese homes to childhood pneumonia.

1   Methods

1.1   Questionnaire

Our study is part of the China, Children, Homes, and Health (CCHH) project, which is investigating associations between home indoor environmental factors and children's health. This is a population-based cross-sectional study. A questionnaire survey was used to investigate health outcomes and home environmental exposure of children less than 8 years old in Nanjing. The questionnaire was consistent with ISAAC (International Study of Asthma and Allergies in Childhood) especially for the questions with children's health. Except for questions that were modified to properly characterize Chinese building characteristics [20], questions are the same as used in Sweden [21], Bulgaria [22] and USA [23] studies. The related questions can be found in Supporting Information.

1.2   Study site

Nanjing, the capital of Jiangsu, is located in the Yangtze River Delta economic zone, on the Yangtze River. It has long been one of the most important and developed cities in China. The city has 8 urban districts, 2 suburban districts, 1 industrial district and 2 counties; see Figure 1. All urban districts and 1 suburban district are located south of the Yangtze River, while 1 suburban district and 1 industrial district are located north of the Yangtze River. The climate

Figure 1   Sketch map of Nanjing showing the urban, suburban, and industrial areas and counties.

is typically hot, humid in summer and cold, humid in winter. Split air conditioners are widely used in Nanjing, both for summer cooling and winter heating.

1.3   Study populations

Twenty-three kindergartens were randomly selected in the 11 districts. No kindergartens were selected in the 2 counties. Questionnaires were distributed by kindergarten teachers to children less than 8 years old as homework for their parents. The children submitted the completed questionnaires to teachers. The survey was performed and completed from December 2010 to March 2011 in Nanjing.

1.4   Data analysis

Statistical analysis was conducted using SPSS for Windows (SPSS Incorporated, SPSS Release 17.0). Binary logistic models were used to test associations between home environmental exposure, building characteristics, life style and the risk of pneumonia infections. Odds ratios were calculated with 95% confidence intervals (CI). *P*-value less than 0.05 indicated a statistically significant level. For those factors that reached significance in binary analysis, a multivariate logistic model was applied to calculate adjusted odds ratios for pneumonia infections. Step forward elimination techniques were used in the multivariate logistic regression model.

2 Results

Total 6461 questionnaires were distributed and 4014 properly filled-out questionnaires were returned, giving a response rate of 65.7%. The response rate was 61.8%, 68.4% and 82.0% for kindergartens in urban, suburban, and industrial areas respectively. We used the kindergarten location as an indication of the location of children's home. Children's homes are usually within walking distance to the kindergarten. Table 1 shows demographic information for investigated children.

The lifetime incidence (at least one incidence) of children's pneumonia in Nanjing is 26.7% (95% CI: 25.3%–28%), 27.2% (95% CI: 25.3%–29.1%), 25.8% (95% CI: 23.7%–28%) and 27.2% (95% CI: 22.4%–32%) for the whole city, urban area, suburban and industrial area respectively. There was no significant difference between locations (P=0.642).

Figure 2 shows crude OR for pneumonia by gender, age and family history of allergy. A family history of allergy is strongly and positively associated with doctor diagnosed pneumonia. Boys have had significantly more pneumonia than girls. Lifetime incidence of pneumonia was not significantly different between children younger than 5 years and older than 5 years old. Thus, young children have a greater incidence for pneumonia.

Table 1 Demographic information of investigated children (n=4014)

|		Total (%)	Urban (%)	Suburban (%)	Industrial (%)
Gender	Male	51.2	27.3	19.4	4.50
	Female	48.8	25.4	19.5	3.90
Age	<3	1.1	1.0	0.0	0.07
	3–4	35.1	22.1	10.5	2.40
	5–6	50.1	24.9	21.3	4.00
	7–8	13.8	4.9	7.1	1.80
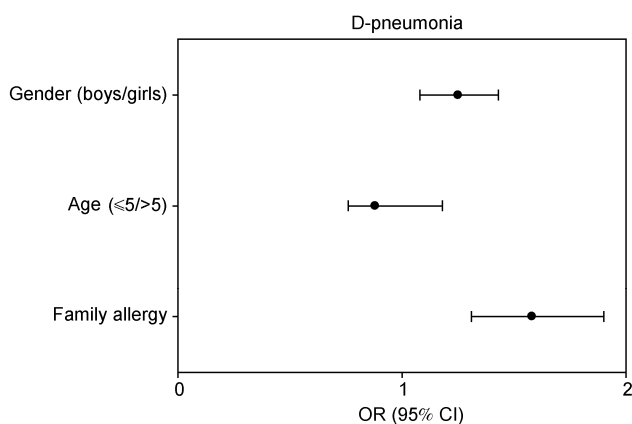
Figure 2 Association between gender, age and family member allergy to diagnosed pneumonia. Variables after slash are used as references in the *Y*-axis.

For lifestyle factors (Figure 3(a)), children with long period of breast feeding (>6 months) reported less pneumonia (OR: 0.81, 95% CI: 0.70–0.93). Daytime child care before the child's kindergarten life by someone other than parents was a risk factor 1.26 (95% CI: 1.10–1.46). Compared to using electricity as fuel for cooking, using coal or natural gas was positively associated with pneumonia, for which OR's are 1.75 (95% CI: 1.16–2.64) and 1.26 (95% CI: 1.03–1.54) respectively. Figure 3(b) shows odds ratios for associations between building characteristic factors and pneumonia. Home ownership, larger living space (>75 m^2) and new furniture were significantly associated with pneumonia (P<0.05). Floors covered by real or laminated wood, and walls covered with paper or emulsion paint were significant risk factors compared to cement (P<0.05). Figure 3(c) shows odds ratios for associations between home ventilation characteristics/odors and pneumonia. Children in homes with smoke removal devices including kitchen fans and hoods, bathroom ventilators, and air conditioner had an increased risk of pneumonia. The perception of pungent odors, dry air, wet air and smells of tobacco smoke in children's room in the previous 3 months also had a significant, positive association with pneumonia. Similar findings were obtained for perception of odors in children's rooms when children were born (data not shown). Figure 3(d) shows odds ratios for associations between indicators of home dampness and pneumonia. Water condensation on windowpanes (both <5 cm of height and > 5 cm of height) at the bottom of windows during wintertime, visible mould, and visible damp stains were significantly and positively associated with children's pneumonia.

Figure 4 shows odds ratios for associations between both other diseases and antibiotic use and diagnosed pneumonia. All diseases except otitis are significantly and positively associated with diagnosed pneumonia; this is especially true for respiratory diseases. Using antibiotics during children aged 0–12 months is also strongly associated with diagnosed pneumonia (OR: 2.70, 95% CI: 2.19–3.32). Table 2 shows the association between diagnosed pneumonia and the number of times using antibiotics by children aged 0–12 months. Risk increased with more antibiotic was used.

Factors which reached significance level in bivariate analyses were used in the multivariate logistic regression model. Results are shown in Figure 5. Frequent tobacco smell, history of family allergy, child care by grandparents or nanny, smoke removal in kitchen and visible damp stains were found to be most significantly associated with pneumonia.

The crude OR's for these variables were adjusted for gender, age distribution, breast feeding, who was responsible for child care children before kindergarten, coal and gas cooking fuel, ownership of the living space, living space area, new furniture, floor covering materials, wall covering materials, ventilator in bathroom, air conditioner, pungent smell, dry air perception, tobacco smell frequently, conden-
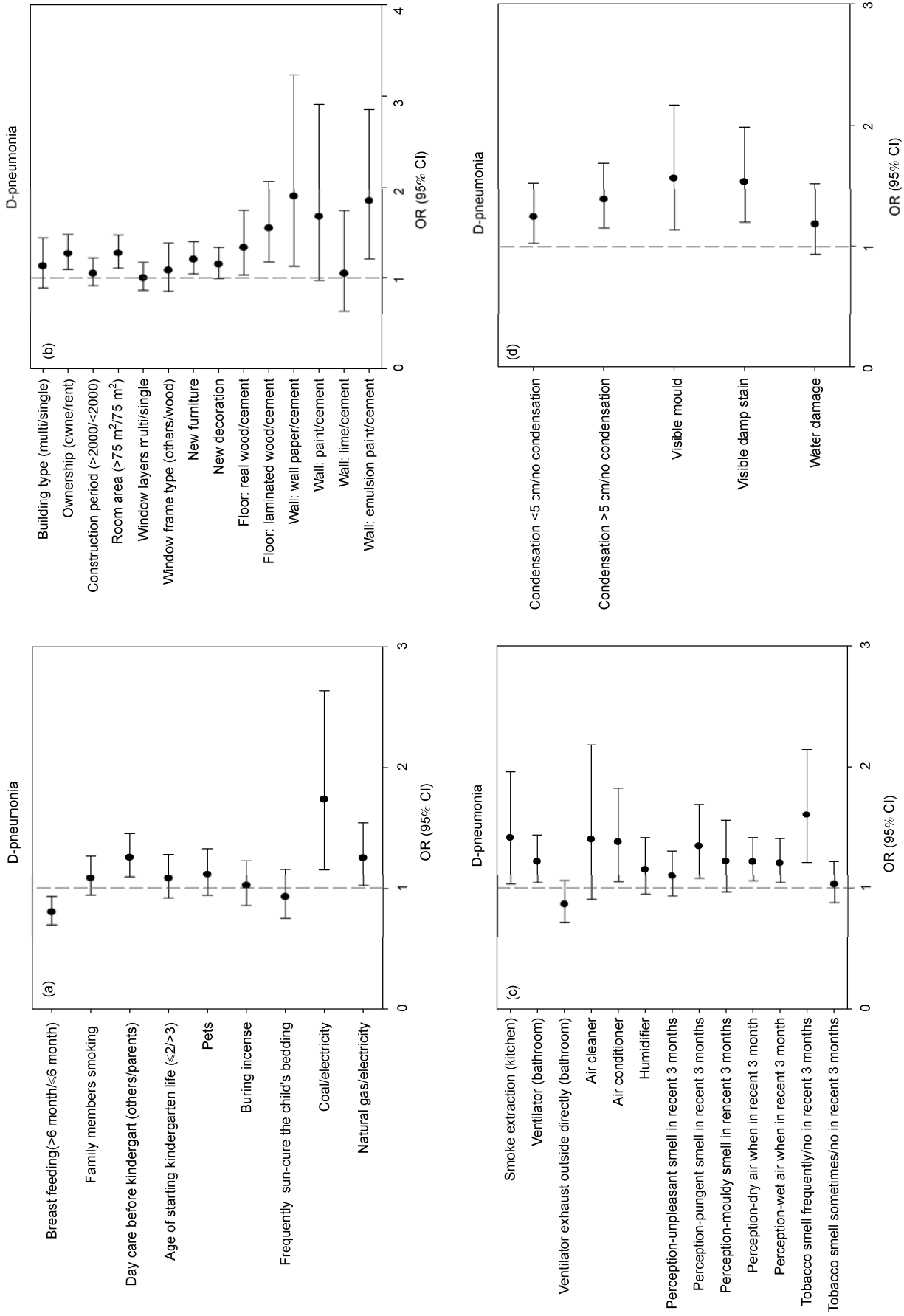
Figure 3   Factors of building characteristics and life styles associated with diagnosed pneumonia. (a) Life styles; (b) building characteristics; (c) ventilation and odors; (d) dampness. Values after the slash were used as references in the *Y*-axis.
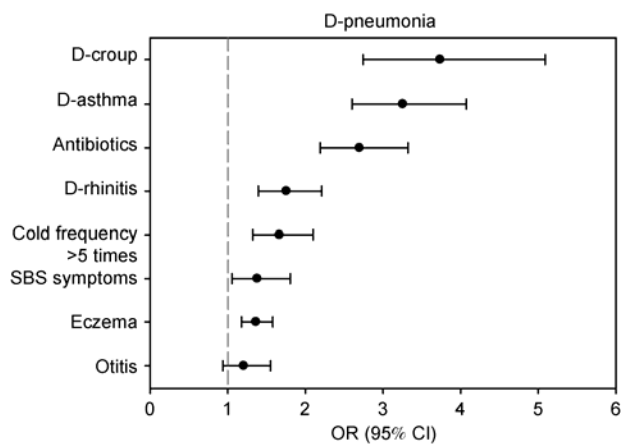
Figure 4   Other diseases associated with diagnosed pneumonia in children in Nanjing.

Table 2   Association between diagnosed pneumonia and times of using antibiotic during children aged 0–12 months

Times of using antibiotic	Crude OR	95% CI	*P*
Never	1	1	–
1	1.41	1.15–1.72	0.001
2	2.02	1.61–2.58	<0.01
3 or more	2.55	2.08–3.14	<0.01
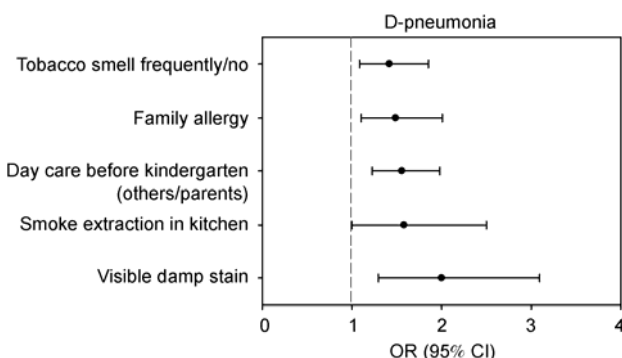
Figure 5   aOR for different factors with pneumonia. Variables after slash were used as references in *Y*-axis.
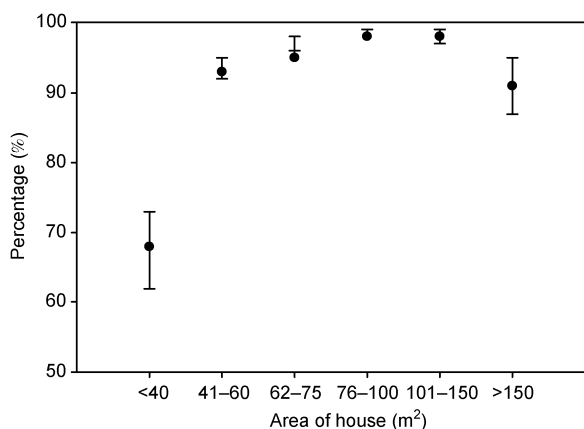
Figure 6   The percentage and 95% CI of family with smoke removal in kitchen.

sation at the bottom of windows, visible mould and visible damp stain.

3 Discussion

The sample size in this study was relatively large with a reasonable good response rate (65.7%). Except for two outlying counties, all districts were included. This study shows that the lifetime incidence of childhood pneumonia was high among children living in modern apartments, without burning of biomass. The lifetime incidence of diagnosed pneumonia in our survey, 26.7%, is close to the 24.8% reported for Liyang, a county near to Nanjing in 1994 [24].

We found that most Nanjing families used natural gas (74.5%) and electricity (33.4%) for cooking. Few families used coal (3.1%) and very few families used biomass (0.4%). Nonetheless, we still found coal to be a significant risk factor for pneumonia, consistent with previous studies [3,15–17]. However, natural gas was also a risk for pneumonia. Thus, using electricity for cooking could significantly reduce the risk of pneumonia.

Child care by parents before kindergarten was associated with less reported pneumonia compared to child care by grandparents or nanny. Table 3 suggests that the association may be biased by socio-economic factors. The percentage for children taken by grandparents or nanny lived in larger, newer, new decorated house with new furniture is much higher than children taken by parents. Furthermore, most children taken by parents have breast feeding period > 6 months, while, most of children taken by grandparents or nanny have breast feeding period < 6 months.

Modern apartments tend to have construction and decorative materials that we found to be significantly and positively associated with pneumonia. These materials include new furniture, floors covered by wood or laminated wood, walls covered by paper or emulsion paint. Whether and

Table 3   Percentage of children cared for by parents or grandparents/nanny compared with factors related to socio-economic status

		Take care by		*P*
		Parents (%)	Grandparents or nanny (%)	
Room size	<75 m^2	59.5	40.5	<0.001
	>75 m^2	51.5	48.5	
Construction period	Before 2000	56.8	43.2	0.016
	After 2000	52.9	47.1	
New furniture	No	58.7	41.3	<0.001
	Yes	52.8	47.2	
New decoration	No	58.0	42.0	<0.01
	Yes	50.3	49.7	
Breast feeding period	>6 months	61.0	39.0	<0.001
	≤6 months	46.9	53.1	

which pollutants emitted from such materials increase the risk of pneumonia will be addressed in Phase 2 of this study.

Our survey of the indoor environment showed that dampness, smell and cooling by air conditioning were significant risk factors for childhood pneumonia. In Nanjing, almost all air conditioners are split air conditioners, which do not deliver fresh air but rather cool, recirculated air. For reasons of energy savings and thermal comfort, people usually close doors and windows tightly when the air conditioners are running. Thus, air conditioner use tends to reduce ventilation. In the winter, outdoor air temperature and absolute humidity is low. If the building is sealed very well, moisture from humans and other activities, such as cooking and bathing, will accumulate and condense on the windows or walls. Lack of ventilation might induce dampness and smell, which are risk factors of pneumonia. Our findings are consistent with those in the literature that higher ventilation rate could decrease the risk of respiratory infectious diseases [25].

Kitchen smoke removal equipment was also found to be strongly and positively associated with pneumonia. However, smoke removal can decrease aerosols and airborne pollutants in the kitchen. Figure 6 shows that a low percentage of small area homes have smoke removal in the kitchen. For such small area homes without smoke extraction, there is seldom cooking. There is about 14.6% rented house, 7.8% non decorated house and 10.0% non new furniture placed house without kitchen removal equipment, while there is only 1.9% owned house, 2.9% new decorated house and 3.9% new furniture placed house without kitchen removal equipment respectively. Cooking removal equipment seems to be associated with socio-economic factors.

Compared to renting, owning a home was positively associated with pneumonia. 46.7% of families who own their home have new decoration and 68.2% families have new furniture, while only 31.2% families who rent their homes have new decoration and 48.7% have new furniture (both $P<0.001$). Furthermore, the finding that larger home size is also a more risk for pneumonia may be due to new furniture and decoration. 66.9% families with home area >75 m^2 have new furniture and 45.6% have new decoration, while 54.7% families with home area <75 m^2 have new furniture and 36.1% have new decoration. This is a further indication that modern housing may have factors which increase the risk of pneumonia.

Although 63.2% of the families in our survey had a member who smokes, we found no significant association between family members smoking and pneumonia. Tobacco smell, however, showed a significant association with pneumonia. The reason may be that smokers do not smoke indoors especially in a room with a child, which reduces the smoking smell as shown in Table 4. However, it should be noted that the tobacco smell was significantly associated with family member smoking (OR: 10.99, 95% CI: 8.94–

Table 4 Percentage of ETS odor in room with/without family member smoking

Family member smoking	Tobacco smell (%)		
	Frequently	Sometimes	Never
Yes	9.3	41.1	49.6
No	0.7	7.7	91.5

13.51).

In this study, we found that the use of antibiotics was strongly associated with diagnosed pneumonia (Table 2). Considering the duration of pneumonia, the association between lengths of antibiotic use with pneumonia might indicate that diagnosed pneumonia was treated by antibiotics. Asthma and allergies, croup, rhinitis, SBS symptoms, eczema and cold frequently are strongly associated with pneumonia, as shown in Figure 4.

4 Conclusions

This paper investigated the association between childhood pneumonia and indoor environment factors in modern homes. The pneumonia incidence is found to be high in Nanjing. Lack of ventilation, gas as cooking fuel, dampness, new furniture, "modern" floor and wall covering materials show significant associations with the incidence of pneumonia. Other factors such as family allergy, child care by non-parents, other respiratory diseases were also reported to be associated with pneumonia. In summary, modern life style and home environment play an important role in developing pneumonia infections among children in Nanjing.

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Supporting Information

Questions in the questionnaries related to this paper

The supporting information is available online at csb.scichina.com and www.springerlink.com. The supporting materials are published as submitted, without typesetting or editing. The responsibility for scientific accuracy and content remains entirely with the authors.