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Changes in children's respiratory morbidity and residential exposure factors over 25 years in Chongqing, China

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Background: Respiratory morbidity and mortality during childhood remains a major challenge for global health. Due to the rapid economic development in Chongqing, we expect substantial temporal changes in respiratory health status and environmental risk factors in children. By leveraging a historical dataset, this study aims to assess the changes in prevalence of respiratory symptoms and diseases, residential exposure factors, and their associations in school-age children over a period of 25 years.

Methods: This study involved two cross-sectional surveys conducted in Chongqing with a 25-year interval (2017 *vs.* 1993). Purpose sampling was used to conduct questionnaire surveys on school-age children in both surveys. Information collected include children's respiratory health outcomes, family residential exposures, demographic information, and parental respiratory disease history. The changes of residential exposures as well as demographics were determined by chi-square test. Odds ratios were calculated to compare the prevalence of children's respiratory symptoms and diseases between the two periods. Associations between children's respiratory outcomes and exposure indicators were assessed using multivariate logistic regressions.

Results: The majority of residential exposure indicators improved in 2017, including sleep in shared room, cooking with coal, poor kitchen ventilation, cooking frequency, and parental smoking. Compared to the 1993 study, the adjusted risk for children's wheezing was lower (OR: 0.38, 95% CI: 0.29, 0.49), but the risk for bronchitis was higher (OR: 1.89, 95% CI: 1.54, 2.31) in the 2017 study. Poor kitchen ventilation and parental smoking were linked to an increased risk of children's wheezing (OR: 1.39, 95% CI: 1.02, 1.90) and bronchitis (OR: 1.51, 95% CI: 1.02, 2.21), respectively, while heating in winter was linked to an increased risk of phlegm (OR: 1.40, 95% CI: 1.03, 1.90) and wheezing (OR: 1.47, 95% CI: 1.07, 2.01) in the 1993 study. However, these residential exposure factors were no longer associated with the children's respiratory diseases in the 2017 study.

Conclusions: Our study found improvement of residential exposures in Chongqing, a decline of prevalence of children's wheezing but an increase of that of bronchitis from 1993 to 2017. Poor kitchen ventilation, heating in winter, and parental smoking were significant risk factors in the 1993 survey but, with significantly reduced prevalence in 2017, were not significantly associated with children's respiratory morbidity in the latter survey.

Keywords: Respiratory morbidity; residential exposures; children

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Introduction

Childhood respiratory morbidity and mortality contribute significantly to global burden of disease. Based on the Global Burden of Disease assessments, lower respiratory infections have always ranked among the top 10 of leading causes of death in children and adolescents (1,2). The prevalence of children's respiratory diseases is increasing in the world, particularly in developing countries (3,4). In general, children are more vulnerable to adverse exposures compared with adults, since some of the organ systems including immune and respiratory system are still in development during childhood (5-7). Spending more than 16 hours per day indoors on average, children are considered to be more vulnerable to residential environmental risk factors (8,9). Hence, the impact of residential exposures on children's respiratory health is of important concerns.

Previous studies have showed that indoor exposures were associated with respiratory morbidity. Two review articles concluded that environmental tobacco smoke exposure was a recognized major influence on the risk of both acute and chronic respiratory illness, associated with respiratory tract infection, wheezing and asthma in young children (4,10). In addition to tobacco exposure, the use of unclean fuels has also been reported as a contributing factor to the prevalence of respiratory disease in children. Indoor cooking with unclean fuels including biomass, kerosene, wood and charcoal was associated with a higher incidence of respiratory symptoms including wheezing (11,12). Studies have also reported that inhaling cooking oil fumes was associated with lung function reductions and respiratory symptoms in children (13,14). Since studies relating to fuels use did not control cooking smoke inhalation, and studies of smoke inhalation did not control fuels use, making their relationship with children's respiratory health unclear.

In 1990s, the China-US Science and Technology Cooperation Project conducted a survey in four Chinese cities including Chongqing, Guangzhou, Lanzhou, and Wuhan, which aimed to study the relationship between air pollution and respiratory health in children (the 1993 study) (15). The study showed that environmental tobacco smoke and household coal use for cooking and heating were risk factors of children's respiratory health (16,17). Chongqing, located in southwest China, one of the largest industrial, transportation and financial center city, was selected as one of point city in the study due to its high-density population and high prevalence of sulfur-rich household coal use in the 1993 study (with the highest ambient concentration of sulfur dioxide among the four cities) (18).

Chongqing has experienced a rapid economic development and urbanization since the 1993 study. Since 2000, a series of measures for environment improvement such as "the clean energy project" and "the blue sky action" have been implemented in Chongqing. All these development and measures resulted in a profound change in household characteristics (e.g., fuels for cooking and heating in winter, kitchen ventilation, cooking habit, parental smoking etc.). For example, with the universal use of clean energy such as natural gas instead of burning coal for cooking and electric air conditioning device instead of coal for heating, the indoor air pollution exposures must have improved substantially.

Chongqing's GDP grew 31 times from 60.853 billion in 1993 to 1.9425 trillion RMB in 2017 (19). It is conceivable that lifestyle and household characteristics in Chongqing have also changed dramatically over the past 25 years. Therefore, it is important to re-evaluate the prevalence of respiratory diseases and relevant risk factors in children. We hypothesize that the economic development in Chongqing over the 25-year period has resulted in changes in residential environmental exposures, children's respiratory morbidity, and the associations between residential exposure factors and respiratory outcomes. This study aims to evaluate the changes in residential exposures, the prevalence of respiratory symptoms and diseases in school-age children as well as their associations.

Methods

Study population

In the 1993 study, two districts were selected with one being an inner city district of relatively higher ambient air pollution level and the other being a suburban district of lower air pollution level. In each district, one primary school was chosen, and 1,452 children in grades 2–6 and their parents accepted our questionnaire survey in the 1993. In the 2017 study, we selected a school close to the original school in the inner city district and the suburban district respectively; and we surveyed 2,126 families of children in grades 1–6.

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was reviewed and approved by the Ethics Committee of Chongqing Medical University (approval number 2017005) as well as the IRB of Duke Kunshan University (approval number FWA00021580). Written informed consent was obtained from all parents/guardians.

Questionnaire survey

The questionnaire for 1993 study was adapted from the American Thoracic Society Epidemiologic Standardization Project questionnaire (ATS-DLD-78-C) (20,21). In the 2017 study, we kept the questionnaire content the same as much as possible with additions and modifications made to reflect some unique changes between 1993 and 2017. In summary, through the survey, we collected information on residential history, lifestyle, household characteristics, and children's and parents' health histories, fuels for home cooking and heating, kitchen ventilation devices, parental smoking status, parental respiratory health status, and children's sleep condition. The collection of questionnaire data in 1993 study has been previously described (7,10). During the 2017 survey, requirements, and precautions for answering questionnaire were explained in detail to all participating children and their parents or guardians. Rigorous quality review on the returned questionnaires was conducted by same investigators. Unqualified questionnaires (i.e., those with too many missing answers and unclear answers) were returned to the participants for refilling. If a questionnaire had some answers missing, the study staff filled the missing information via a follow-up telephone call.

Children's respiratory morbidity outcomes were determined from the multiple health outcomes collected in the questionnaires and were defined as follows. (I) Cough: a 'yes' answer to any of the following questions: 'Has this child ever coughed when he/she has a cold?' or 'Has this child ever coughed without colds?'. (II) Phlegm: a 'yes' answer to any of the following questions: 'Does this child have phlegm from the chest when he/she has colds?' or 'When this child does not have a cold, does he/she have phlegm from the chest?'. (III) Wheezing: a 'yes' answer to any of the following questions: 'Has this child ever wheezed when he has colds?' or 'Has this child ever wheezed when he/she does not have colds?' or 'Has this child ever had wheezing on most days or nights?'. (VI) Asthma: a 'yes' answer to the question 'Has a doctor ever diagnosed asthma in this child?'. (V) Bronchitis: a 'yes' answer to the question 'Has a doctor ever diagnosed bronchitis in this child?'.

Statistical methods

We used *t* tests and chi-square tests to compare the residential exposure factors, demographics, and parental respiratory diseases between the two studies. We calculated odds ratios to compare the prevalence of children's respiratory symptoms and diseases between the two periods, adjusting for covariates for residential, demographics, and parental respiratory diseases. Unconditional logistic regression models were used to analyze the relationship between residential exposures and children's respiratory diseases and symptoms in each of the two studies. Important covariates, including age, sex, parental education level, parental asthma, and parental bronchitis, were adjusted in logistic regression models. Statistical significance was achieved when $P<0.05$. SPSS 22.0 software (SPSS Inc., Chicago, IL, USA) was used to conduct data analysis.

Results

Comparison in demographics, residential factors, and parental respiratory diseases between the two study times

Residential factors, demographics, and parental respiratory diseases of two studies were presented in *Table 1*. Compared to those of the 1993 study, most of the indoor exposure risk factors that were considered as indicators of residential environment have improved in the 2017 study, such as sleep in shared room (χ^2 14.2, $P<0.001$), cooking with coal (χ^2 58.5, $P<0.001$), poor kitchen ventilation (χ^2 197.7, $P<0.001$), paternal (χ^2 275.5, $P<0.001$) and maternal smoking (χ^2 4.8, $P=0.029$), whereas cooking frequency per week increased (χ^2 65.1, $P<0.001$). For demographics, children's age was older (9.39±1.60 *vs.* 8.73±1.16, $P<0.001$), while maternal education level was higher in the 2017 study (χ^2 65.7, $P<0.001$). Parental asthma and bronchitis prevalence rates were lower among participants in the 2017 study (paternal asthma: χ^2 12.8, $P<0.001$; maternal asthma: χ^2 8.7, $P=0.003$; paternal bronchitis: χ^2 36.0, $P<0.001$; maternal bronchitis: χ^2 19.5, $P<0.001$).

Change in children's respiratory morbidity

Adjusted ORs for children's respiratory morbidity in 2017 in reference to 1993 were shown in *Table 2*. The prevalence of children's wheezing in 2017 (5.8%) was significantly lower than that in 1993 (16.5%) (OR: 0.377, 95% CI: 0.288, 0.494). However, the prevalence of children's bronchitis in 2017 (23.6%) was significantly higher than that in 1993 (17.7%) (OR: 1.888, 95% CI: 1.540, 2.314). No statistically significant difference was found in the prevalence of children's cough, phlegm, and asthma between the two studies.

Table 1 Comparison in residential exposures, demographics, and parental respiratory diseases prevalence between 1993 and 2017

Factors	N (%) in 1993	N (%) in 2017	χ^2	P
Sleep in shared room	717 (49.6)	918 (43.2)	14.2	<0.001*
Cooking with coal	74 (5.1)	20 (0.9)	58.5	<0.001*
Poor kitchen ventilation	489 (33.7)	295 (13.9)	197.7	<0.001*
Heating in winter	441 (30.5)	619 (29.1)	0.8	0.382
Cooking frequency			65.1	<0.001*
<10[a]	334 (23.1)	276 (13.0)		
≥16[a]	896 (61.8)	1,537 (72.3)		
Paternal smoking	1,113 (77.3)	936 (49.1)	275.5	<0.001*
Maternal smoking	29 (2.0)	22 (1.1)	4.8	0.029
Sex of children: boy	705 (48.6)	1,092 (51.4)	2.7	0.099
Paternal low education	1,124 (78.4)	1,597 (76.3)	2.2	0.138
Maternal low education	1,251 (88.0)	1,627 (77.2)	65.7	<0.001*
Paternal asthma	38 (2.6)	22 (1.1)	12.8	<0.001*
Maternal asthma	36 (2.5)	25 (1.2)	8.7	0.003*
Paternal bronchitis	139 (9.6)	95 (4.5)	36.0	<0.001*
Maternal bronchitis	103 (7.1)	80 (3.8)	19.5	<0.001*

*, P<0.01; [a], cooking frequency means home cooking frequency per week; [b], paternal/maternal low education means paternal/maternal education below undergraduate.

Table 2 Adjusted ORs for children's respiratory morbidity in 2017 in reference to that in 1993

Variables	Prevalence, %		OR[a]	95% CI	P
	1993	2017			
Cough[a]	46.6	43.0	0.888	0.759, 1.040	1.142
Phlegm[b]	16.9	14.8	0.967	0.795, 1.217	0.878
Wheezin[g][c]	16.5	5.8	0.377	0.288, 0.494	<0.001
Asthma	3.4	3.6	1.362	0.880, 2.109	0.166
Bronchitis	17.7	23.6	1.888	1.540, 2.314	<0.001

Adjusted for variables significant in result 3.1, including age, maternal education, paternal respiratory diseases, sleep in shared room, cooking with coal, poor kitchen ventilation, cooking frequency per week and parental smoking. [a], the variable of cough means cough with or without cold. [b], the variable of phlegm means phlegm with or without cold. [c], the variable of wheezing means wheezing with or without cold, or wheezing on most days or nights.

Associations between children's respiratory morbidity and residential exposures, demographics, and parental respiratory diseases

Residential exposures

Multivariable logistic regression analysis was conducted to test association between children's respiratory morbidity and residential exposures as well as parental factors (education level, having asthma or bronchitis) in 1993 and 2017, respectively. Results are shown in *Table 3*. The adjusted analysis of the 1993 data found that poor kitchen ventilation and parental smoking were associated with increased risks for children's wheezing (OR: 1.39, 95% CI: 1.02, 1.90) and

Table 3 Adjusted odds ratios for children's respiratory morbidity associated with residential exposures and parental factors (education level, having asthma or bronchitis) in 1993 and 2017, respectively

Factors	Cough		Phlegm		Wheezing		Asthma		Bronchitis	
	OR (95% CI)	P	OR (95% CI)	P[a]	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
In 1993 (n=1,452)										
Cooking with coal	0.92 (0.56, 1.51)	0.739	0.70 (0.34, 1.47)	0.350	1.01 (0.51, 2.01)	0.979	–[a]	–[a]	1.11 (0.54, 2.29)	0.773
Poor kitchen ventilation	1.02 (0.81, 1.29)	0.850	1.32 (0.98, 1.80)	0.072	1.39 (1.02, 1.90)	0.039*	0.93 (0.48, 1.80)	0.827	0.87 (0.63, 1.20)	0.392
Heating in winter	1.14 (0.90, 1.45)	0.266	1.40 (1.03, 1.90)	0.031*	1.47 (1.07, 2.01)	0.016*	1.02 (0.52, 1.97)	0.959	1.10 (0.80, 1.51)	0.567
Parental smoking[b]	1.17 (0.90, 1.52)	0.231	1.14 (0.80, 1.63)	0.472	1.34 (0.91, 1.96)	0.137	1.10 (0.52, 2.35)	0.797	1.51 (1.02, 2.21)	0.037*
Cooking frequency ≥10[c]	0.88 (0.65, 1.20)	0.424	1.29 (0.86, 1.92)	0.215	0.99 (0.65, 1.52)	0.961	0.81 (0.32, 2.03)	0.652	0.76 (0.45, 1.30)	0.322
Cooking frequency ≥16[c]	1.04 (0.80, 1.35)	0.772	1.16 (0.82, 1.65)	0.392	0.91 (0.63, 1.32)	0.636	0.97 (0.46, 2.07)	0.941	1.25 (0.87, 1.81)	0.226
Sleep in shared room	1.14 (0.92, 1.42)	0.228	1.18 (0.88, 1.58)	0.273	1.08 (0.80, 1.46)	0.615	1.52 (0.81, 2.86)	0.191	1.14 (0.85, 1.55)	0.378
Age (year)	1.01 (0.92, 1.11)	0.886	1.03 (0.91, 1.17)	0.630	0.96 (0.84, 1.09)	0.537	0.84 (0.63, 1.11)	0.224	0.84 (0.73, 0.96)	0.009*
boys	0.92 (0.74, 1.14)	0.453	0.84 (0.63, 1.12)	0.238	0.67 (0.50, 0.91)	0.009*	0.50 (0.27, 0.95)	0.034*	0.75 (0.56, 1.01)	0.055
Paternal low education	0.80 (0.59, 1.09)	0.153	0.90 (0.60, 1.33)	0.588	1.03 (0.68, 1.56)	0.899	1.29 (0.54, 3.10)	0.572	0.59 (0.40, 0.86)	0.006*
Maternal low education	0.92 (0.63, 1.36)	0.684	1.10 (0.66, 1.83)	0.725	0.84 (0.50, 1.41)	0.515	0.83 (0.29, 2.34)	0.722	1.32 (0.80, 2.19)	0.277
Paternal asthma	0.97 (0.47, 2.00)	0.937	1.20 (0.52, 2.78)	0.673	5.52 (2.58, 11.81)	0.000*	7.00 (2.55, 19.21)	0.000*	1.87 (0.83, 4.22)	0.132
Maternal asthma	1.48 (0.70, 3.09)	0.302	1.49 (0.65, 3.40)	0.347	1.73 (0.78, 3.85)	0.176	1.24 (0.30, 5.10)	0.767	2.00 (0.91, 4.40)	0.086
Paternal bronchitis	1.52 (1.04, 2.21)	0.029*	1.67 (1.08, 2.60)	0.022*	1.50 (0.94, 2.37)	0.086	1.67 (0.72, 3.88)	0.231	3.13 (2.08, 4.71)	0.000*
Maternal bronchitis	1.27 (0.81, 2.00)	0.296	1.44 (0.84, 2.46)	0.180	2.15 (1.28, 3.61)	0.004*	1.78 (0.66, 4.84)	0.257	2.81 (1.72, 4.59)	0.000*
In 2017 (n=2,126)										
Cooking with coal	2.51 (0.91, 6.91)	0.076	0.31 (0.04, 2.47)	0.271	1.37 (0.20, 9.29)	0.749	2.56 (0.40, 16.50)	0.322	0.38 (0.08, 1.89)	0.235
Poor kitchen ventilation	0.78 (0.59, 1.03)	0.083	0.87 (0.58, 1.30)	0.503	0.80 (0.42, 1.53)	0.495	1.06 (0.49, 2.30)	0.874	0.85 (0.61, 1.21)	0.373
Heating in winter	1.20 (0.98, 1.48)	0.078	1.22 (0.92, 1.61)	0.170	1.16 (0.75, 1.80)	0.516	1.01 (0.58, 1.78)	0.959	0.9790.76, 1.24)	0.816
Parental smoking	1.14 (0.95, 1.38)	0.160	1.28 (0.99, 1.66)	0.062	1.14 (0.76, 1.71)	0.536	1.28 (0.77, 2.14)	0.336	1.03 (0.83, 1.29)	0.774
Cooking frequency ≥10[b]	0.83 (0.64, 1.08)	0.174	0.85 (0.59, 1.23)	0.380	1.20 (0.70, 2.06)	0.505	0.89 (0.44, 1.80)	0.743	1.40 (0.92, 2.13)	0.115
Cooking frequency ≥16[b]	0.95 (0.72, 1.26)	0.724	0.84 (0.57, 1.26)	0.402	0.85 (0.44, 1.61)	0.613	0.73 (0.32, 1.66)	0.449	1.18 (0.83, 1.66)	0.359
Sleep in shared room	1.02 (0.84, 1.23)	0.870	1.06 (0.81, 1.38)	0.692	1.27 (0.84, 1.92)	0.253	1.12 (0.67, 1.89)	0.666	1.09 (0.86, 1.37)	0.470
Age (year)	0.97 (0.91, 1.03)	0.334	0.93 (0.85, 1.01)	0.083	0.89 (0.78, 1.01)	0.078	0.85 (0.72, 1.01)	0.062	0.85 (0.79, 0.91)	0.000*
boys	0.94 (0.78, 1.13)	0.505	0.92 (0.71, 1.20)	0.549	0.80 (0.53, 1.20)	0.275	0.56 (0.33, 0.95)	0.032*	1.05 (0.84, 1.31)	0.652
Paternal low education[c]	0.77 (0.60, 1.00)	0.047*	0.64 (0.46, 0.89)	0.008*	1.19 (0.69, 2.05)	0.542	0.65 (0.35, 1.21)	0.178	0.69 (0.52, 0.92)	0.012*
Maternal low education[c]	0.75 (0.58, 0.97)	0.030*	0.98 (0.70, 1.38)	0.913	0.75 (0.45, 1.27)	0.285	0.59 (0.32, 1.10)	0.096	0.76 (0.57, 1.02)	0.069
Paternal asthma	0.81 (0.32, 2.06)	0.659	2.38 (0.87, 6.51)	0.091	9.11 (3.22, 25.80)	0.000*	25.80 (8.87, 74.98)	0.000*	1.46 (0.54, 3.97)	0.461
Maternal asthma	1.44 (0.59, 3.49)	0.420	0.68 (0.21, 2.23)	0.529	8.15 (3.11, 21.39)	0.000*	5.02 (1.37, 18.35)	0.015*	0.71 (0.25, 2.01)	0.524
Paternal bronchitis	1.05 (0.65, 1.70)	0.850	1.11 (0.62, 2.01)	0.726	0.82 (0.32, 2.09)	0.683	0.48 (0.13, 1.83)	0.282	4.75 (2.89, 7.80)	0.000*
Maternal bronchitis	2.88 (1.65, 5.05)	0.000*	2.16 (1.18, 3.93)	0.012*	1.90 (0.79, 4.60)	0.153	1.18 (0.32, 4.32)	0.802	2.98 (1.72, 5.17)	0.000*

The variables were adjusted for each other in multivariate regressions. *, P<0.05. [a], the absence OR of the association between cooking with coal and asthma in 1993 was because the sample in the yes group was zero. [b], cooking frequency means home cooking frequency per week. [c], paternal/maternal low education means paternal/ maternal education below undergraduate.

for bronchitis (OR: 1.51, 95% CI: 1.02, 2.21), respectively, while heating in winter was significantly associated with an increased risk of phlegm (OR: 1.40, 95% CI: 1.03, 1.90) and an increased risk for wheezing (OR: 1.47, 95% CI: 1.07, 2.01). However, these residential exposure factors were no longer associated with the children's respiratory diseases in the 2017 study.

Demographics

Demographic indicators included children's age, sex, and parental education. Older age in children was associated with a lower risk of bronchitis in both studies (OR: 0.84, 95% CI: 0.63, 1.11 in the 1993 study and OR: 0.85, 95% CI: 0.72, 1.01 in the 2017 study). Boys had a lower risk of wheezing in 1993 (OR: 0.67, 95% CI: 0.50, 0.91) and asthma in 1993 (OR: 0.50, 95% CI: 0.27, 0.95) and in 2017 (OR: 0.56, 95% CI: 0.33, 0.95) than girls. The children whose father had lower education attainment (below undergraduate) had lower risk of bronchitis (OR: 0.59, 95% CI: 0.40, 0.86) in the 1993 study and a lower risk of cough (OR: 0.77, 95% CI: 0.60, 1.00), phlegm (OR: 0.64, 95% CI: 0.46, 0.89), and bronchitis (OR: 0.69, 95% CI: 0.52, 0.92) in the 2017 study. Children whose mothers had lower education attainment had a lower risk of cough only in the 2017 study (OR: 0.75, 95% CI: 0.58, 0.97).

Parental respiratory diseases

Paternal asthma was significantly associated with children's wheezing in both 1993 (OR: 5.52, 95% CI: 2.58, 11.81) and 2017 (OR: 9.11, 95% CI: 3.22, 25.80). Paternal asthma was also significantly associated with children's asthma in both 1993 (OR: 7.00, 95% CI: 2.55, 19.21) and in 2017 (OR: 25.80, 95% CI: 8.87, 74.98). However, maternal asthma was significantly associated with children's wheezing (OR: 8.15, 95% CI: 3.11, 21.39) and asthma (OR: 5.02, 95% CI: 1.37, 18.35) only in the 2017 survey. Paternal bronchitis was associated with children's cough (OR: 1.52, 95% CI: 1.04, 2.21), phlegm (OR: 1.67, 95% CI: 1.08, 2.60), and bronchitis (OR: 3.13, 95% CI: 2.08, 4.71) in 1993, and only associated with bronchitis (OR: 4.75, 95% CI: 2.89, 7.80) in 2017. Maternal bronchitis was associated with children's wheezing (OR: 2.15, 95% CI: 1.28, 3.61) and bronchitis (OR: 2.81, 95% CI: 1.72, 4.59) in 1993, and was associated with cough (OR: 2.88, 95% CI: 1.65, 5.05), phlegm (OR: 2.16, 95% CI: 1.18, 3.93) and bronchitis (OR: 2.98, 95% CI: 1.72, 5.17) in 2017.

Discussion

This study compared the residential exposures, the prevalence of respiratory symptoms and diseases adjusted for covariates, and their associations among school-age children in Chongqing between 1993 and 2017.

This research found that most residential exposure factors, except home cooking frequency, had been improved in 2017 compared to those in 1993. High cooking frequency was considered as a risk factor due to its relation with cooking fumes and non-clean fuels (e.g., coal), which had been reported to be a risk factor of respiratory disease in children. However, with the popularity of natural gas, range hood and exhaust fans, the negative impact of high cooking frequency on children's respiratory system was significantly weakened. Therefore, the residential potential exposures included in this study showed an overall trend of improvement, which was likely to be beneficial to the respiratory health of children.

Consistent with our hypothesis, the prevalence of wheezing in 2017 (5.8%) was significantly lower than that in 1993 (16.5%) and similar to the prevalence (5.2%) reported in 2015 previously for Chongqing school children (22). After controlling for the covariates, the prevalence of wheezing remained lower than that in 1993 study (OR: 0.377, 95% CI: 0.288, 0.494). In contrast, prevalence of children's bronchitis in 2017 (23.6%) rose compared to study in 1993 (17.7%), and the result remained the same after controlling for covariates (OR: 1.888, 95% CI: 1.540, 2.314). In the context of the overall improvement of residential environment, the rising prevalence of bronchitis suggests that factors other than residential exposures may have played a larger role in the development bronchitis. Studies found an increased risk for bronchitis associated with traffic-related air pollution (23,24), which was in line with the rapid increase of vehicle population in Chongqing in recent years. Studies also reported viral or bacterial infection, being obese, cold weather, air quality had influence on bronchitis (25-28), which were not taken into account in this analysis. We note that the lack of data on many other factors is a major limitation of our study. Similarly, the prevalence of bronchitis among children in Chongqing was 24.40% in 2013 as reported in a previous study using the same evaluation method (29). However, we could not find data showing long-term temporal trend in bronchitis prevalence in Chongqing or in China.

In the multivariate analyses of the 1993 data, poor

kitchen ventilation was associated with higher prevalence of children's wheezing after controlling for cooking with coal, which suggests that cooking fumes may have contributed to children's wheezing. Also, heating in winter was a risk factor for phlegm and wheezing. A study has found that heating in winter can worsen indoor air quality (30), leading to an increased risk for respiratory symptoms. Children exposed to parental smoking increased their risk for bronchitis by 1.5 times in 1993. However, these factors were no longer associated with children's respiratory symptoms and diseases in 2017, suggesting that the improvement of residential factors weakened its effect on respiratory diseases. A review of 52 studies also found that improving home environments helped reduce respiratory problems such as asthma and chronic bronchitis (31).

We found that both paternal asthma and maternal asthma significantly increased children's risks for wheezing and asthma. This finding is consistent with previous findings that parental asthma increased children's asthma risk in Chongqing (32) and elsewhere (33-35). This child-parent association may be due to the genetic heredity and/or due to the fact that children and their parents are exposed to many common environmental factors. Future studies are recommended to examine the reasons for this association.

This study has several notable limitations. Firstly, the relationship between residential factors and health effects is a very complex issue. This study is only a cross-sectional comparison of two surveys conducted with a 25-year interval. The comparison may have missed other unmeasured time-varying factors (e.g., medical care, immunizations, pets, nutrition, and exercise) (36-39). Due to data constraints, we can only conduct a comparative analysis on the existing variables. Secondly, the data in prevalence of respiratory symptoms and diseases as well as residential exposure factors in this study were derived from self-report rather than measurements, which are subject to recall bias.

As the global health community continues to prioritize child and adolescent health during the Sustainable Development Goal era, careful attention should also be placed on identifying, detecting, and controlling related environmental risk factors for childhood respiratory health.

Conclusions

Our study found improvements of several residential exposure factors, a significant decline of prevalence for wheezing, and a significant increase of prevalence for bronchitis from 1993 to 2017 in school children of Chongqing. Poor kitchen ventilation, heating in winter and parental smoking as important risk factors for children's respiratory symptoms and diseases in 1993. However, these factors were largely improved compared to the 1993 conditions and no longer associated with children's respiratory morbidity in 2017.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by the Chongqing Medical University Ethics Committee (No. 2017005) and Duke Kunshan University IRB (No.

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