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Ten cities cross-sectional questionnaire survey of children asthma and other allergies in China

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Asthma, rhinitis and eczema (allergic or non-allergic) have increased throughout the world during the last decades, especially among children. Changes in the indoor environment are suspected to be important causes. China has experienced a dramatic change in indoor environmental exposures during the past two decades. However, such changes and their associations with children's asthma and other health aspects have not been thoroughly studied. China, Children, Homes, Health (CCHH), Phase I, was a cross-sectional questionnaire survey of 48219 children 1–8 years old in 10 Chinese cities during 2010–2012. The questionnaire includes the International Study of Asthma and Allergies in Childhood (ISAAC) core health questions and additional questions regarding housing, life habits and outdoor environment. In health analyses, children aged 3–6 years old were included. The prevalences of doctor diagnosed asthma varied from 1.7% to 9.8% (mean 6.8%), a large increase from 0.91% in 1999 and 1.50% in 2000. The prevalence of wheeze, rhinitis and atopic eczema (last 12 months) varied from 13.9% to 23.7%, 24.0% to 50.8% and 4.8% to 15.8%, respectively. Taiyuan had the lowest prevalences of all illnesses and Shanghai the highest, except for wheeze-where the highest value was for Urumqi. We found (1) no obvious association between disease prevalences and ambient PM_{10} concentrations and (2) higher prevalences of disease in humid climates with hot summers and cold winters, but with no centrally heated buildings. Associations between the diseases and economic status as indexed by Gross Domestic Product (GDP) requires further study.

environmental health, indoor air quality, homes, exposure, urbanization

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Asthma prevalence has increased worldwide during the last decades [1–7]. The magnitude of increase has generally been smaller in low-income countries, but the rates of increase may be accelerating [1,4,5]. The International Study of Asthma and Allergies in Childhood (ISAAC) reported that the highest prevalences of asthma in children aged 6–7 years were in the UK, Australia, New Zealand and Ireland, while the lowest prevalences were in Indonesia, Albania, Romania, Georgia and Greece [1]. In many parts of the world, a large fraction of children have or have had asthma, wheeze, rhinitis or eczema [1,2]. The cost, family burden and impaired life quality due to asthma and allergies are severe public health problems. It is anticipated that there will be about 300 million people suffering from asthma by 2025 [6].

Neither genetic factors [7], outdoor environmental pollution [8–12], racial factors [13], nor socio-economic status [14] can wholly explain this dramatic increase. People spend a large part of their time indoors and pre-school children spend a longer time in homes compared with adults [15,16]. The indoor environment, especially in homes, has been implicated as having an important role in inducing and/or exacerbating asthma and allergies among children [17–25].

The ISAAC project was started in 1990 in Germany and New Zealand with the aim of quantifying the prevalence and characterizing the severity of asthma and allergies worldwide [26]. Studies had been conducted in 236 centers in 98 countries [27] before 2009. However, ISAAC studies lack data on indoor environmental and building related risk factors. The idea to study "asthma and the home environment" was initiated in Sweden because of the Allergy Inquiry (a 1987–1989 governmental inquiry) to identify causes of the dramatic increase of allergic children in Sweden. The Swedish study, "Dampness in Buildings and Health" (DBH) was started in 2000 with the aim of characterizing associations between building dampness and asthma and allergies among children. Its hypothesis and background were based on scientific state-of-the-art reviews [17,28–33]. Questionnaires and experimental protocols were designed for a multidisciplinary study involving environmental science, engineering, chemistry and microbiology in addition to medicine and public health. By 2010, studies built on the platform of the Swedish study had been carried out in several countries [19,22,34–38].

The prevalences of asthma and allergies have, in some western countries, recently stabilized or even decreased [39,40]. These changing trends coincide with the currently slower rate of change in indoor environment exposures in these countries. China, a developing country, is experiencing rapid and dramatic changes in indoor environment exposures due to its rapid modernization and urbanization. National surveys of asthma in Chinese children aged 0–14 years in 1990 and 2000 by the Childhood Asthma Collaborative Group of China [41] as well as a number of other studies indicate that asthma and allergies have increased in China [4,7,42–51]. However, information about indoor exposure has been included to only a small extent and in only a few studies [52,53].

In September 2010, we launched the project China, Children, Homes, Health (CCHH) in 10 major cities in China. Ten universities are involved in CCHH. There are two phases: Phase I is a cross-sectional questionnaire study of the prevalence of children's asthma, allergies and airway infections, and home environmental exposures (2010.11–2012.4) (See Table S1); Phase II will be a case-control study with measurements of pollutants in sampled air, dust and urine (2012.11–). The objectives of the CCHH research project are:

(1) to investigate the prevalences of asthma, allergies and airway infections in major Chinese cities with different climates, outdoor air quality, and economic level;

(2) to investigate and compare indoor environmental aspects of sick and healthy children's homes;

(3) to compare risk and protective factors in different cities of China;

(4) to compare findings from CCHH with those of other countries and regions outside of mainland China;

(5) to provide epidemiological data as a foundation for the prevention of asthma and allergies among children in China.

This paper reports some basic data from all cities as well as some historic trends in the prevalences of asthma, allergies and the percentage of children who have had one or more episodes of pneumonia.

1 Subjects and methods

1.1 Sites studied and children selected

The CCHH study was carried out in 10 cities in different geographic regions of China with different per capita economic statuses and outdoor environmental pollution levels (Table 1 and Figure 1). Every city included urban areas. Some cities included rural or suburban areas. Kindergartens or daycare centers or primary schools were randomly selected in each city.

1.2 Questionnaire design and pilot study

CCHH research used questions from the ISAAC study [56] about children's asthma, and allergies. Questions from the Swedish DBH study about the home environments [19] were adapted so as to be relevant to Chinese home characteristics [57]. The questionnaire was tested in a pilot study of 100 children in Chongqing in April 2010, and thereafter adjusted to improve readability. For details about questionnaire design, see articles for specific CCHH cities [58–68].

Table 1 Economic status, geography, climate and PM_{10} concentration of the investigated cities in CCHH studies

Cities (from north to south)	Economic status (Income, per capita GDP, kRMB)[a)]	Dry/humid [54]	Type of climate [55]	Annual mean concentration of PM_{10} ($\mu g/m^3$) [b)]	
				2001	2010
Harbin	37.0	Sub-humid	Severe cold	134.7	102.6
Urumqi	44.9	Dry	Severe cold	203.6	139.1
Beijing	75.9	Sub-humid	Cold	175.2	122.3
Taiyuan	44.3	Sub-humid	Cold	203.7	89.2
Xi'an	38.3	Sub-humid	Cold	156.5	126.1
Nanjing	63.7	Humid	Hot summer and cold winter	140.0	112.7
Shanghai	76.1	Humid	Hot summer and cold winter	101.7	79.3
Wuhan	59.0	Humid	Hot summer and cold winter	150.4	107.0
Chongqing	27.6	Humid	Hot summer and cold winter	141.5	102.5
Changsha	66.4	Humid	Hot summer and cold winter	181.0	83.6

a) From the annual report of each city, using 2010 data (except Taiyuan, 2009); b)from the Ministry of Environmental Protection of China.

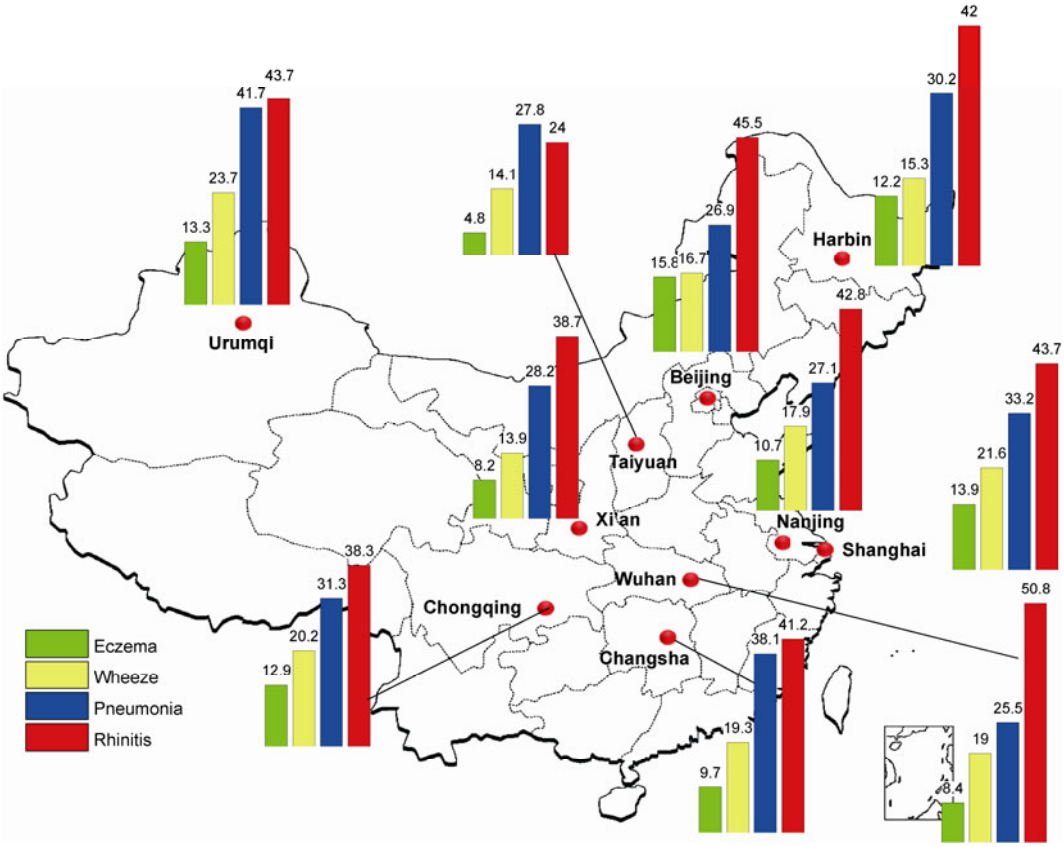

Figure 1 Prevalences (%) of rhinitis, wheeze, and atopic eczema in the last 12 months and pneumonia (at least one episode), for children 3–6 years old in all cities except Taiyuan (3–5) and Wuhan (5–6) years old.

1.3 Procedure for Phase I study

The procedure for the questionnaire survey was as follows: We first contacted the director of each kindergarten. After he or she agreed on participation, questionnaires were distributed by the responsible teachers in each class to the children's parents or legal guardians. Finally, parents returned the questionnaires to the teachers, and we collected the completed questionnaires from the teachers.

The data were input and statistically analyzed by SPSS software.

2 Results

In the CCHH investigation Phase I, parents of 48219 children aged 1–8 responded to the questionnaire, yielding a 76.9% average response rate. Table 2 presents detailed information on children's ages, numbers of respondents, and response rates. Non-respondents were tracked by short questionnaires in Chongqing. A sample of 300 children was randomly selected from those who had not responded in the cross-sectional study, and 206 responded. The five

Table 2 Number of respondents and response rates in investigated cities

Cities	Age (years)	Number of respondents	Response rate (%)
Harbin	2–8	2506	64.1
Urumqi	2–7	4618	81.7
Beijing	1–8	5876	65.0
Shanghai	1–8	15266	85.3
Nanjing	1–8	4014	65.7
Xi'an	1–8	2020	83.5
Taiyuan	1–6	3700	82.2
Wuhan	1–8	2193	91.4
Changsha	1–8	2727	59.0
Chongqing	1–8	5299	74.5

questions in the short questionnaires asked about home site (location), gender, wheezing in the last 12 months, visible damp stains and family smoking. There were no significant differences between responses to the short questionnaire, and responses to the same questions in the long questionnaire (see Table S2).

Distributions of gender, age and family allergic histories among investigated children in 10 cities are shown in Table 3. As the number of children in age groups 1, 2, 7 and 8 were small in most cities, further analyses of health outcomes were for children 3–6 years of age, except for Taiyuan (3–5 years of age) and Wuhan (5–6 years of age). Table 4 shows the age-adjusted prevalences of illnesses (3–6 years, except Taiyuan (3–5) and Wuhan (5–6)). Prevalences for the last 12 months of wheeze, rhinitis, and eczema, as well as the percentages of children who had had one or more lifetime episodes of pneumonia, are shown in Figure 1.

Asthma was determined as a "yes" reply to the question "Has your child ever been diagnosed with asthma by a doctor?". In Figure 2, the findings of the CCHH ten city study in 2010–2011 are compared with mean prevalences among 0–14 year old children in 1990 and 2000 [41]. All prevalences are normalized against 1990 data. Figure 3 shows the same comparison but with actual (non-normalized) data. Prevalences of doctor-diagnosed asthma have increased faster during the last ten years than during the decade from 1990 to 2000. Urumqi, Wuhan, Beijing and Shanghai had the most rapid increase in the last decade.

Figures 4 and 5 show ecological comparisons. Southern cities, humid all year but cold in winter and without heating,

Table 3 Percentages by gender, allergy in the family and children's ages in CCHH Phase I cities[a)]

City name	Gender (%)		Allergy in family (%)	Age (%)							
	Male	Female	Yes	1	2	3	4	5	6	7	8
Harbin	50.3	49.7	13.3	0	1.8	10.3	21.2	23.0	27.3	14.4	2.0
Urumqi	53.6	46.4	19.8	0	2.1	24.3	36.0	30.4	6.9	0.1	0.0
Beijing	52.4	47.6	23.4	0.5	2.2	24.1	28.7	26.3	16.3	1.3	0.6
Shanghai	50.9	49.1	19.4	0.2	0.1	5.0	37.2	29.4	22.6	5.2	0.3
Nanjing	51.2	48.8	15.8	0.1	1.0	11.4	23.6	25.2	24.9	12.0	1.8
Xi'an	53.3	46.7	9.2	0.1	1.4	19.7	28.1	28.6	19.7	2.2	0.2
Taiyuan	52.3	47.7	11.5	0.2	4.5	30.4	36.4	26.8	1.7	0.0	0.0
Wuhan	52.7	47.3	16.9	0.5	0.1	1.4	3.6	4.8	10.3	32.2	47.1
Changsha	53.3	46.7	15.4	0.2	2.8	24.5	34.2	31.2	6.6	0.4	0.1
Chongqing	51.3	48.7	11.1	0.3	2.4	20.0	32.4	29.6	14.1	1.1	0.1

a) Age 1 means age ⩽ 1, age 2 means age > 1 and ⩽ 2, and so on.

Table 4 Age adjusted prevalences of symptoms and illnesses in children 3–6 years old

	Harbin	Urumqi	Beijing	Shanghai	Nanjing	Xi'an	Taiyuan[e)]	Wuhan[f)]	Changsha	Chongqing
Wheeze ever	19.6	35.3	22.3	27.9	23.4	20.2	21.7	31.2	27.0	26.7
Wheeze last 12 months	15.3	23.7	16.7	21.6	17.9	13.9	14.1	19.0	19.3	20.2
Dry cough last 12 months	11.7	11.9	19.4	19.7	18.5	15.0	7.9	18.4	16.0	18.4
Doctor diagnosed asthma	2.9	3.9	6.3	9.8	8.8	3.0	1.7	7.4	6.9	8.2
Rhinitis ever	55.3	48.9	57.7	55.2	54.6	56.5	38.6	58.7	54.2	51.6
Rhinitis last 12 months	42.0	43.7	45.5	43.7	42.8	38.7	24.0	50.8	41.2	38.3
Rhinitis on pet exposure	1.0	4.3	3.3	4.6	2.0	2.1	2.5	9.3	2.0	2.7
Rhinitis on pollen/grass exposure	1.9	6.3	6.9	7.6	8.0	6.4	1.1	19.4	11.5	3.6
Doctor diagnosed Rhinitis	2.2	9.8	7.9	11.6	8.8	3.7	2.7	23.9	8.0	6.2
Eczema ever[a)]	33.1	15.3	34.7	23.4	28.4	29.0	13.6	26.0	29.9	30.4
Eczema last 12 months[b)]	12.2	13.3	15.8	13.9	10.7	8.2	4.8	8.4	9.7	12.9
Croup	3.2	6.3	4.3	7.6	4.2	4.5	4.0	5.8	5.9	6.3
Pneumonia	30.2	41.7	26.9	33.2	27.1	28.2	27.8	25.5	38.1	31.3
Common cold ⩾6 times last 12 months	6.0	7.6	9.5	8.5	9.9	7.1	4.7	6.1	7.9	18.1
Ear infection[c)]	8.3	11.9	14.9	10.5	7.8	7.7	9.0	16.2	7.7	7.8
Food allergy[d)]	22.2	16.4	23.9	19.4	20.5	12.9	12.7	17.0	17.6	16.9

a) Has your child ever had an itchy rash (eczema), which intermittently for at least 6 months? b) In the last 12 months, has your child had itchy skin rash? c) Has your child ever had ear infections? d) Has your child ever developed itchy skin, rash, diarrhea, swollen lips, or swollen eyes as a result of eating the foods below? e) Age adjusted for 3–5 year old children; f) Age adjusted for 5–6 year old children.

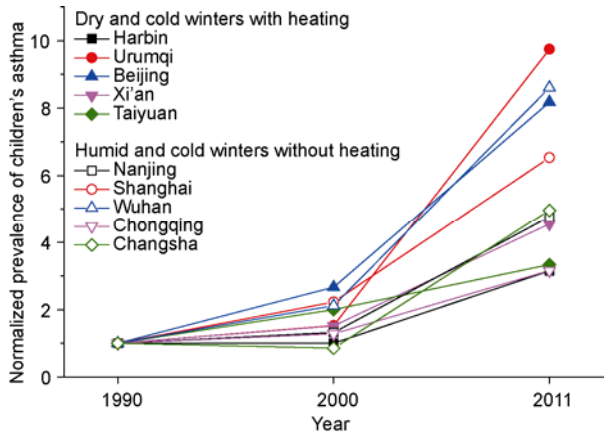

Figure 2 Prevalences of children's asthma normalized for 1990.

had asthma prevalences of >6.9%. The dry northern cities, which do have heating during winter, had asthma prevalences of <4% with the exception of Beijing, with asthma prevalence of 6.3%. There are no associations in ecological analyses between wheeze, rhinitis, eczema and pneumonia; and climate, GDP/capita or ambient PM_{10}. Table 1 also shows that ambient PM_{10} decreased in all cities during the last 10 years, the years that asthma has increased more rapidly. Figure 5 shows an association between doctor-diagnosed asthma and GDP/capita, which is, however, distorted by the outlier Chongqing.

General characteristics of the study population, housing characteristics, and home dampness and odor reports are given in Tables S3–S5.

3 Discussion

The CCHH survey covered 10 major cities in China with different climates, geographies and per capita economic status. In total, there were 48219 children (and homes), of whom 43591 were 3–6 years old, included in the analyses of health outcomes. The mean response rate, 76%, is reasonably high. This study is subject to the limitations inherent in any cross-sectional survey. Data used for analyses were collected retrospectively and relied on parental reports; our findings could therefore be subject to recall bias. A strength of the study is that core ISAAC questions have been validated [69] as have questions on indoor exposures [70, 71]. Non-respondents were reached by a short survey in Chongqing. There were no significant differences in the prevalences of wheezing in the last 12 months between responders and non-responders to the long questionnaire, which indicates that neither selection nor non-response biases are likely present. The possible influence of bias on specific topics is discussed in the articles from each city

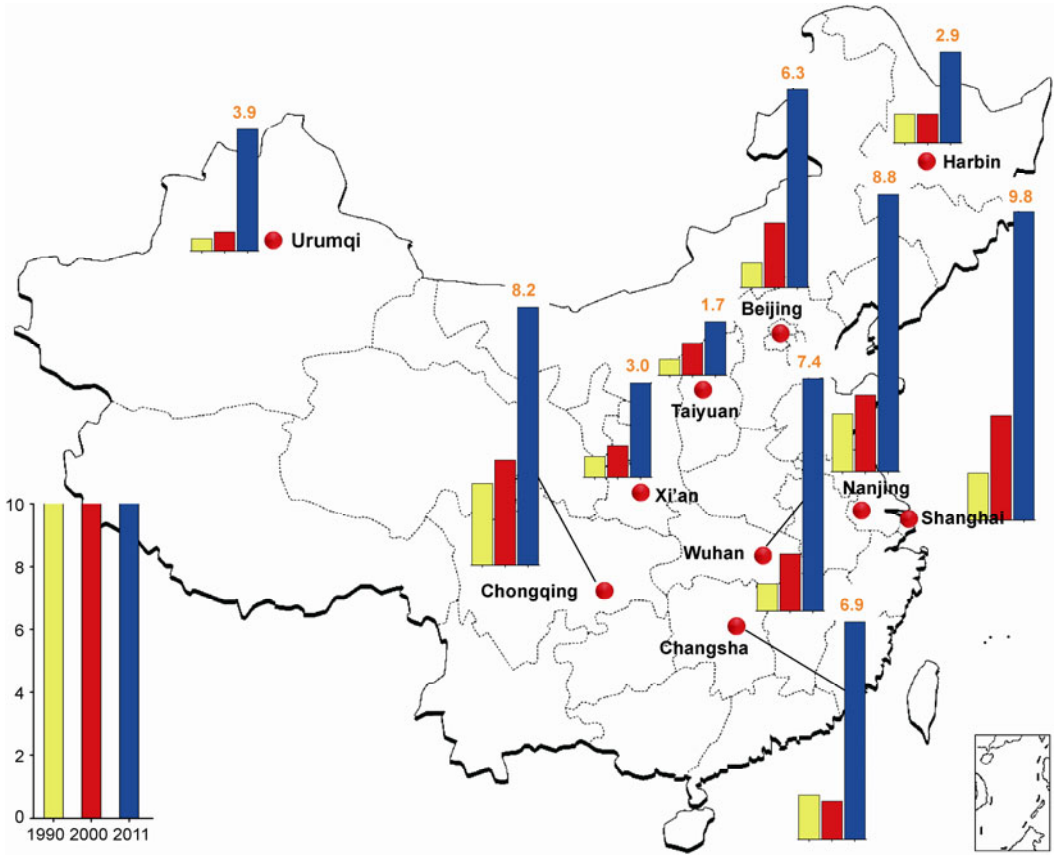

Figure 3 National trends for children's asthma in the cities investigated (3–6 years old, except for Taiyuan (3–5) and Wuhan (5–6) compared with the prevalence for 0–14 years old children 1990, 2000 [41]).

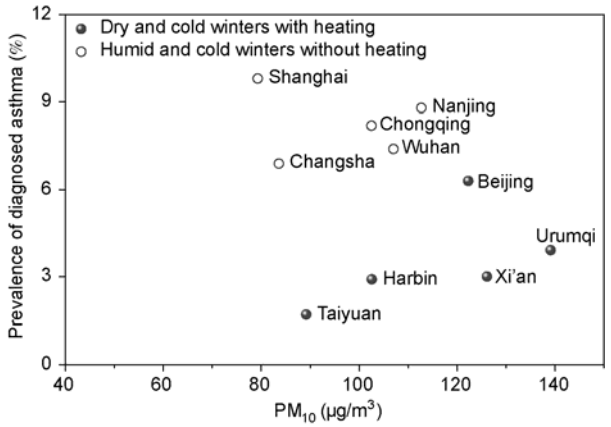

Figure 4 Correlation between outdoor PM_{10} concentration in 2010 and prevalence of asthma in 2011.

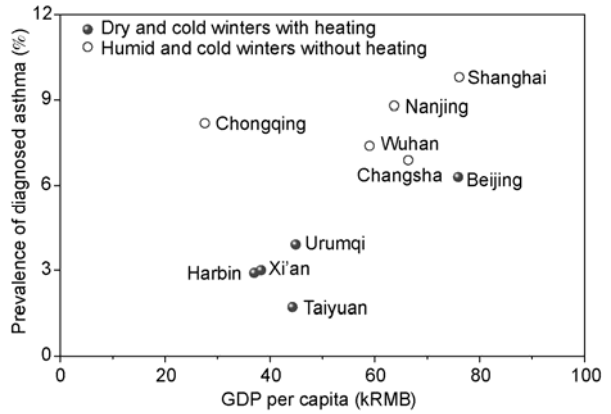

Figure 5 Correlation between GDP per capita in 2010 and prevalence of asthma in 2011.

[58–68].

The prevalences of doctor-diagnosed asthma in CCHH cities varied from 1.7% to 9.8% (mean 6.8%). This represents a great increase from 0.91% in 1999 (287329 children) and 1.50% in 2000 (299193 children in 27 cities of China). The prevalences of wheeze, rhinitis and eczema (last 12 months) varied from 13.9% to 23.7%, 24% to 50.8% and 4.8% to 15.8% respectively. For all symptoms, Taiyuan had the lowest prevalences, whereas the more developed eastern cities had the highest prevalences, with the exception of Urumqi, which had the highest prevalence of wheeze. Ecological analyses show no obvious association between diseases and ambient air pollution (PM_{10}), or economic status as indexed by GDP (Gross Domestic Product) per capita, but suggest that prevalences were higher in humid climates where summers are hot, winters cold, and there is no heating. In comparison with earlier studies, the prevalences of parentally reported wheeze, rhinitis and eczema, and parentally reported doctor-diagnosed asthma were high, indicating increased prevalences of these symptoms and diseases. Other recent studies [4,46–51]are in agreement with these findings.

The comparisons in Figures 2 and 3 between prevalences of doctor-diagnosed asthma in 1990, 2000 and 2011 are important. However, because our samples of children 1–2 and 7–8 years old were small, the present CCHH study reports health outcomes for children 3–6 years old. The national studies of 1990 and 2000 [41] surveyed children 0–14 years old, so that a direct comparison is not possible. Nonetheless, the CCHH survey of 10 cities shows that children's asthma has increased. Moreover, the increase has accelerated since 2000 (Figure 2).

The prevalences of wheeze, rhinitis and atopic eczema are not as different between cities as the prevalences of doctor-diagnosed asthma (Figures 1 and 3). The difference in prevalences between parentally reported doctor-diagnosed asthma (Figure 3) and parentally reported symptoms in different regions may be due to regional differences in health care systems. The comparison between Figure 1 (parental reported wheeze) and Figure 3 (parental reported doctor-diagnosed asthma) may partly reflect differences in how likely it is that a child is taken to a clinic for a diagnosis of asthma as well as for rhinitis.

The reported percentage of children who have had at least one doctor-diagnosed episode of pneumonia is high (25.5%–41.7%), especially given that urban pneumonia rates are generally lower than those of rural areas, where there is extensive exposure to smoke from burning of biomass [72]. The children in this study are primarily living in new and modern apartments with lower air exchange rates than old apartments (see articles from Nanjing [65], and Urumqi [59] for further discussion).

4 Conclusions

Prevalences of "allergic" diseases and symptoms have increased in large Chinese cities. More than half of the 3–6 year old children surveyed have had at least one manifestation of wheeze, rhinitis or eczema, and more than one-fourth of children have had at least one episode of pneumonia.

The changes in indoor environmental exposure caused by the modernization of China may in part explain the increasing prevalence of the studied diseases. Certainly, further analyses and research (composition and size effect of PM, e.g.) are necessary to unravel the riddles behind the rapid increases. In Phase II, case-control studies in which pollutants in air, dust and urine are measured, will be done. Nation-wide collaborative research among inter-disciplinary fields and groups will be needed.

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Supporting Information

Table S1 Questionnaire used in CCHH Phase I
Table S2 Comparison between short questionnaires and Phase I questionnaires in Chongqing
Table S3 Summary of general characteristics of the study populations, children 1–8 years old (%)
Table S4 Summary of building characteristics in the investigated regions, children 1–8 years old (%)
Table S5 Dampness and odor indices in homes in the investigated regions, children 1–8 years old (%)

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