Article

Childhood Wheeze, Allergic Rhinitis, and Eczema in Hong Kong ISAAC Study from 1995 to 2015

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Abstract: Background: The prevalence of allergic diseases has been increasing in developing areas but has reached a plateau in many developed areas. Regular surveys are imperative to assess the disease burden for the prioritization of resource allocation. Objectives: We examined the change in the prevalence of wheezing, allergic rhinitis (AR), and eczema in school-aged children with possible associative factors and possible health effects of school air quality. Methods: This was the third repeated cross-sectional study conducted in 2015–2016 using the International Study of Asthma and Allergies in Childhood (ISAAC) protocol. Our first and second surveys were conducted in 1994–1995 and 2000–2001, respectively. Regarding the third survey, we recruited 3698 children aged 6–7 from 33 local schools in 18 districts. Air quality, temperature, and humidity were also measured. The changes in prevalence, multiple regression, and GLIMMIX procedure were analyzed. Results: From our first survey to our third survey, the increased prevalences for lifetime wheeze, current wheeze, lifetime rhinitis, current rhinitis, current rhinoconjunctivitis, lifetime chronic rash, and current chronic rash were 4.2%, 2.1%, 12.5%, 12.6%, 14.2%, 3.9%, and 4.1%, respectively. Increased prevalence of parental atopy had the strongest association with an increased prevalence of each of these seven health outcomes. There was no significant association between school air pollutant levels and the prevalence of health outcomes. Conclusions: There was an increase in the prevalence of wheezing, allergic rhinitis, and eczema across the surveys. The most important associated risk factor identified was the increased prevalence of a parental history of atopy.

Keywords: ISAAC; wheeze; allergic rhinitis; eczema; parental atopy; school air quality

1. Key Messages

1.1. What Is the Key Question?

Has the prevalence of wheezing, allergic rhinitis (AR, and eczema condition been leveling off in developed areas as illustrated by Phase I (in the mid 1990s) and Phase III (in the early 2000) ISSAC2000s) ISAAC?

1.2. What Is the Bottom Line?

This is the first study to show a continual increase in wheeze, AR, and eczema prevalence using ISAAC methodology over 21 years in Hong Kong, a well-developed area.

1.3. Why Read on?

We identified significant associative factors for the observed increase in the prevalence that may cast light on preventive measures for these health outcomes that carry a significant global burden.

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2. Introduction

Childhood allergic diseases are prevalent worldwide, posing a significant disease burden on patients, their families, and society [1–5]. The International Study of Asthma and Allergies in Childhood (ISAAC), the largest worldwide collaborative research project, showed that there was a wide global variation in the prevalence of asthma, allergic rhinitis (AR), and eczema with an increasing trend in developing countries and reaching a plateau in developed countries from the mid-1990s to the early 2000s [6]. Regular surveys are essential to assess the disease burden in terms of prevalence, economic impact, and effects on quality of life to prioritize resource allocation [7,8].

The first (1st) ISAAC survey was conducted in Hong Kong in 1994–1995, and showed that the prevalence of allergic diseases in school children aged 6 to 7 years old was comparable to that in Singapore and Great Britain [9]. The second (2nd) repeated cross-sectional survey in 2000–2001 showed a leveling off of lifetime asthma, lifetime wheeze, and current wheeze but a significant increase in the prevalence of current severe asthma symptoms, lifetime rhinitis, current rhinitis, and lifetime eczema [10]. Some environmental factors were associated significantly but not completely with the observable change. While viral infection is a well-known trigger for asthma exacerbation, local studies noted that it accounted for less than half of asthma exacerbation in clinics or hospital settings [11,12]. Instead, environmental air pollutants, including fine particles $PM_{2.5}$ and coarse PM (PMC; 2.5–10 μm aerodynamic diameter), were confirmed to be significantly associated with hospital admission for childhood asthma [13] and emergency hospital admissions for respiratory diseases, respectively [14]. Most studies on the impact of environmental air pollutants on child health have focused on residential areas. A French study showed that poor air quality at school was related to an increased prevalence of allergic diseases [15]. In Hong Kong Special Administrative Region, China (HKSAR), around 20% of 650 primary schools are situated close to the main road, as defined by the Transport Department, at a mean distance of 20.5 m with a standard deviation (SD) of 24.7 m [16]. Yet there have not been any local studies on the health effect of school air pollution on school children.

It has been more than a decade since our second ISAAC survey was conducted. We aimed to repeat the third (3rd). We also took this opportunity to study the effect of school air quality on the health outcomes assessed. The information may have potential implications for health care and urban planning and possible intervention strategies for disease prevention.

3. Aims and Objectives

We examined the change in the prevalence of wheezing, AR, and eczema in school children in HKSAR and explored possible associative demographic, family factors, respiratory tract infection (RTI), and other environmental factors. In addition, we also examined the possible association between school air quality by collecting indoor and outdoor air pollutants data with the prevalence of the seven primary health outcomes assessed, including lifetime wheeze, current wheeze, lifetime rhinitis, current rhinitis, current rhinoconjunctivitis, lifetime chronic rash, and current chronic rash.

4. Materials and Methods

4.1. Study Design

This was the 3rd of a series of repeated cross-sectional questionnaire surveys conducted in 2015–2016 involving a questionnaire survey and collecting indoor and outdoor air pollutants data at the schools when the questionnaires were distributed. The methodology was the same as the previous 2 surveys except for the slightly modified sampling frame. We recruited children from local schools located in 3 regions (Hong Kong Island (HK), Kowloon (KLB), and New Territories (NT)) at that time. Schools were selected from 18 refined districts within the aforementioned 3 regions geographically and administratively divided in HKSAR. Based on the modified population density, this approach gives a better representation of the child population in HKSAR and the additional measurement of

air pollutants at school. The indoor environmental and health-related risk factors that affect the prevalence of wheezing, allergic rhinitis, and eczema were assessed by the core questionnaire, and the health outcomes were assessed by the environmental questionnaire provided by ISAAC [6,17,18] (see Appendix A). The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKWC IRB) (IRB ref. number: UW12-499).

4.2. Subjects

Same as our previous studies that recruited children aged 6 to 7 years [19]. We randomly approached each school until two schools from each district agreed to participate. Two classes with children aged 6 or 7 from each school were chosen. Children outside the specified age range were included in the data collection but excluded from the analysis. Parents were requested to fill in the ISAAC core and environmental questionnaire that included most of the potential demographic and indoor risk environmental factors reported in previous literature and 2 added new questions about traffic at residence [9,19].

4.3. School Air Quality Monitor

Air pollutants were measured indoors (in 2 classrooms) and outdoors from Monday to Friday (night and day) for two weeks when the questionnaire was distributed by the school to parents. Concentrations of particulate matter (PM_{10}) were measured using filter-based samples collected by a PM_{10} monitor (TSI AM510) charged with a pump. The TSI AM510 allows measurement of $PM_{2.5}$ or PM_{10} at one time only. A pilot run showed that the pump's tubing was easily blocked when measuring $PM_{2.5}$. Hence, PM_{10} measurement was chosen in order to obtain reliability. NASA data on the air quality in different areas of Hong Kong was provided by Hong Kong University of Science and Technology upon request. We used the data to estimate the air quality of $PM_{2.5}$ at each school location [20]. Concentrations of nitrogen dioxide (NO_2), ozone (O_3), and sulfur dioxide (SO_2) were measured by passive diffusion samplers using NO_2 monitor (Z-1400XP), O_3 monitor ZDL-1200 and SO_2 monitor (Z-1300), respectively. Temperature and humidity data were also collected. During collection, the whole monitor was placed at a fixed position at one meter above ground level.

4.4. Estimation of Ambient Air Quality at Residential Locations

Geographical coordinates of the participants' residential locations were identified from their residential addresses provided in the questionnaire. Surface extinction coefficients derived from NASA satellite data were used to estimate the residential ambient particulate air quality ($PM_{2.5}$ and PM_{10}) based on the residential locations [19]. The association of our outdoor air quality data with surface extinction coefficients (SEC) and aerosol optical depth (AOD) data from NASA satellites and air quality data from the nearest monitoring stations of the Hong Kong Environmental Protection Department (EPD) were determined. The satellite data and air quality data from EPD are freely available online. The information was used to adjust for the variation in exposure at home.

4.5. Data Analysis

According to the instructions from ISAAC, missing answers on the questionnaire were merged with negative answers in the analysis. The Chi-square test was used to test the difference in the health outcomes (all categorical variables) related to wheeze, AR, and eczema between our 3rd survey and the 1st and 2nd surveys.

Trend analysis was conducted by Chi-square test across the 3 surveys. The trend in prevalence was considered significant only if both comparisons in 2015 vs. 2000 and 2015 vs. 1994 were significant with $p < 0.025$ and showed the trend in the same direction. Multi-test was adjusted by the Bonferroni correction. Multiple logistic regression was used to reveal any association between the change in the prevalence of potential risk factors and the change in the prevalence of 7 primary health outcomes. A total of 21 risk factors were

included in the questionnaire [10]. The potential risk factors included in the regression analysis were those associated with a particular health outcome in univariate analysis ($p < 0.05$). They showed significant changes in prevalence between the study periods ($p < 0.05$). We also added an ordinal variable for the "study period" in the regression analysis and set our 1st survey as the reference period.

For our 3rd survey, the indoor and outdoor 10-day mean concentrations (microgram/m^3) of each pollutant for each school were calculated. In addition, estimation of socioeconomic data (household size and individual income) was obtained from the census department in the tertiary planning unit (TPU) in Large Street Block Group (LSBG). A multi-level analysis model was employed. Firstly, a basic model was developed to detect any association between potential independent risk factors with 7 primary health outcomes using the Pearson chi-square test or exact Fisher test, followed by multiple logistic regression analysis.

The 2nd level of analysis involved 2 steps. First, between-school variability ("schools" variance) and between-class variability ("classes" variance) of the measured air pollutants with 7 primary health outcomes were estimated using generalized linear mixed models (SAS MIXED procedure) [15]. Then, significant factors identified in the basic model by multiple logistic regression, temperature and humidity data collected, and residential ambient particulate level derived from NASA satellite data was adjusted in the final analysis for the association between significant air pollutants and the 7 health outcomes by using generalized linear mixed models. All data were analyzed using SAS/PC (Cary, NC, USA) V9.1. A significance level of $p < 0.05$ was used for all analyses.

5. Results

The results of our first and second surveys were reported previously [10,11]. For our third survey, there were 3698 participants (51.4% male) aged 6 to 7 years old from 33 primary schools in HKSAR, compared to 3618 (50.9% male) in our first and 4448 (54.1% male) in our second survey.

The prevalences of wheezing, AR, and eczema in these three surveys were compared (Table 1). There had been a significant increase in the prevalences of all seven primary health outcomes. From our first survey to our third survey, the increased prevalences for lifetime wheeze and current wheeze, lifetime rhinitis, current rhinitis, current rhinoconjunctivitis, lifetime chronic rash, and current chronic rash were 4.2%, 2.1%, 12.5%, 12.6%, 14.2%, 3.9% and 4.1% respectively. There had also been a significant increase in the prevalence of secondary health outcomes, including the 12-month prevalence of nocturnal awakening with wheezing, nocturnal cough, and being kept awake by rash, and severe rhinitis interfering with daily activities.

Nine of twenty-one potential risk factors studied were found to be associated with the health outcomes in all three study periods and showed a significant prevalence change (Table 2).

All factors showed an increase in prevalence except for recurrent RTI in the last 12 months from the survey (≥ 4) ($p < 0.01$ for all).

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Table 1. Self-reported prevalence of wheezing, rhinitis, and eczema.

Questions		Prevalence in %			Prevalence Change across 3 Study Periods	*p*-Value	*p*-Value	Chi-Square Test for Trend **
		2015–2016	**2000–2001**	**1994–1995**		**2015 vs. 2000**	**2015 vs. 1994**	
		n = 3698	*n* = 4448	*n* = 3618	*p*-Value			
Wheeze								
Wheeze ever (lifetime wheeze)	Yes	21.00	17.20	16.80	<0.01	<0.01	<0.01	↑
Wheeze in last 12 months (current wheeze)	Yes	11.30	9.40	9.20	<0.01	<0.01	<0.01	↑
Wheezing episodes in last 12 months	≥4	2.50	2.30	2.30	0.81	0.61	0.64	-
Night awakenings by wheeze in last 12 months *	>0	5.10	4.00	2.90	<0.01	0.01	<0.01	↑
Speech limitation during wheeze in last 12 months *	Yes	1.00	1.00	0.80	0.60	<0.01	0.44	-
Doctor diagnosed asthma ever	Yes	6.60	7.90	7.80	0.06	0.03	0.05	-
Exercise-induced wheeze in last 12 months *	Yes	6.00	7.70	7.10	0.01	<0.01	0.06	-
Nocturnal cough in past 12 months *	Yes	32.60	26.00	22.10	<0.01	<0.01	<0.01	↑
Allergic rhinitis								
Allergic rhinitis ever	Yes	35.30	33.90	31.90	<0.01	0.2	<0.01	-
Rhinitis ever (lifetime rhinitis)	Yes	51.40	42.40	38.90	<0.01	<0.01	<0.01	↑
Rhinitis in last 12 months (current rhinitis)	Yes	47.70	37.40	35.10	<0.01	<0.01	<0.01	↑
Rhinitis with itch eyes in last 12 months (current rhinoconjunctivitis)	Yes	27.80	17.20	13.60	<0.01	<0.01	<0.01	↑
Rhinitis interfering with daily activities *	M-S #	7.50	4.80	2.10	<0.01	<0.01	<0.01	↑
Hay fever ever	Yes	1.00	1.40	1.20	0.27	0.13	0.50	-
Eczema								
Chronic rash ever (lifetime chronic rash)	Yes	9.60	5.40	5.70	<0.01	<0.01	<0.01	↑
Chronic rash in last 12 months (current chronic rash)	Yes	8.30	4.20	4.20	<0.01	<0.01	<0.01	↑
Chronic rash at typical areas	Yes	8.10	3.60	4.20	<0.01	<0.01	<0.01	↑
Age rash first occurred *	<2	46.20	31.80	29.20	<0.01	<0.01	<0.01	↑
Rash all cleared in last 12 months *	Yes	26.70	19.90	28.10	<0.01	<0.01	0.18	-
Kept awake by rash in last 12 months *	>0	4.90	3.00	1.60	<0.01	<0.01	<0.01	↑
Eczema ever	Yes	30.90	30.70	28.10	0.01	0.87	<0.01	-

* Subgroup with positive response to wheeze in last 12 months, rhinitis in last 12 months, and chronic rash in last 12 months. # Moderate to severe. ** The trends in prevalence were recognized if both *p*-values in 2015 vs 2000 and 2015 vs 1994 were less than 0.025. ↑ Increasing trend across the three study periods.

Table 2. Prevalence of potential risk factors with significant change across 3 study periods.

Question	Prevalence in %			*p*-Value	*p*-Value	Prevalence Change across 3 Study Periods	Chi-Square Test for Trend **
	2015–2016 (*n* = 3698)	**2000–2001 (*n* = 4448)**	**1994–1995 (*n* = 3618)**	**2015 vs. 2000**	**2015 vs. 1994**		
	Yes	Yes	Yes			*p*-Value	
Born in Hong Kong	92.90	87.90	88.70	<0.01	<0.01	<0.01	↑
Siblings (≤2)	97.70	94.40	78.40	<0.01	<0.01	<0.01	↑
Hospital admission for RTI in 1st 12 months (≥4)	2.00	2.30	0.40	0.41	<0.01	<0.01	↑
RTI in last 12 months (≥4)	11.30	9.70	34.90	0.02	<0.01	<0.01	↓
Currently smoking mother	4.68	5.26	2.05	0.25	<0.01	<0.01	↑
Mother smoke during the child's 1st 12 months of life	4.00	4.34	0.72	0.48	<0.01	<0.01	↑
Currently smoking father	28.23	30.04	21.45	0.08	<0.01	<0.01	↑
Father smoke during the child's 1st 12 months of life	28.37	29.36	23.22	0.34	<0.01	<0.01	↑
Parental history of atopy	50.60	49.70	45.00	0.45	<0.01	<0.01	↑

RTI, respiratory tract infection; ↑ significant increase across 3 study periods, ↓ significant decrease across 3 study periods. ** The trends in prevalence were recognized if both *p*-values in 2015 vs. 2000 and 2015 vs 1994 were less than 0.025.

The results of multiple logistic regression to examine if there is any association between significant prevalence change in potential risk factors, study period effect, and the increased prevalence of the seven primary health outcomes are tabulated in Table 3a–c, respectively. There were associations between the increased prevalence of parental history of atopy with the increased prevalence of each of the seven primary health outcomes; the increased prevalence of having small sibship size with the increased prevalence of lifetime wheeze, lifetime rhinitis, current rhinitis, and current rhinoconjunctivitis, and the increased prevalence of reporting frequent hospitalization for RTI in the 1st 12 months of life with the increased prevalence of lifetime wheeze and current wheeze. In addition, the increased prevalence of maternal smoking during the child's 1st year of life was associated with lifetime wheeze and current wheeze, while that of current maternal smoking was

associated with current rhinoconjunctivitis. The study period effect referred to potential environmental risks or protective factors that could not be addressed in the environmental questionnaire; for example, immigrants from mainland China, and the westernization of lifestyle. An increased prevalence of parental atopy had the strongest association with an increased prevalence of each of these seven health outcomes, and the odds ratio (OR) ranged from 2.35 to 3.12.

Table 3. (**a**) Multiple logistic regression to assess association between risk factors and prevalence change in lifetime wheeze and current wheeze. (**b**) Multiple logistic regression to assess association of risk factors with prevalence change in lifetime rhinitis, current rhinitis, and current rhinoconjunctivitis. (**c**) Multiple logistic regression to assess association of risk factors with prevalence change in lifetime chronic rash and current chronic rash.

(**a**)

	Wheeze Ever (Lifetime Wheeze)		Wheeze in Last 12 Months (Current Wheeze)	
	Odds Ratio (95% CI)	*p*-Value	Odds Ratio (95% CI)	*p*-Value
Siblings (≤2)	1.26 (1.04–1.52)	0.02	1.17 (0.92–1.49)	0.20
Hospitalization for RTI in 1st 12 months of age (≥4)	2.25 (1.64–3.08)	<0.01	2.36 (1.64–3.38)	<0.01
Currently smoking mother (Yes)	1.03 (0.76–1.38)	0.86	1.29 (1.13–1.90)	0.19
Mother smoke during the child's 1st 12 months of life (Yes)	1.49 (1.08–2.06)	0.02	2.09 (1.41–3.10)	<0.01
Parental history of atopy (Yes)	2.69 (2.43–2.97)	<0.01	2.62 (2.29–2.99)	<0.01
Study period				
Study 1 (1994–1995)	Reference	Reference	Reference	Reference
Study 2 (2000–2001)	0.93 (0.82–1.06)	0.30	0.91 (0.77–1.06)	0.93
Study 3 (2015–2016)	1.21 (1.06–1.37)	<0.01	1.12 (0.95–1.31)	0.12

(**b**)

	Rhinitis Ever (Lifetime Rhinitis)		Rhinitis in Last 12 Months (Current Rhinitis)		Current Rhinoconjunctivitis	
	Odds Ratio (95% CI)	*p*-Value	Odds Ratio (95% CI)	*p*-Value	Odds Ratio (95% CI)	*p*-Value
Siblings (≤2)	1.19 (1.03–1.36)	0.02	1.30 (1.12–1.50)	<0.01	1.47 (1.20–1.81)	<0.01
Hospitalization for RTI in 1st 12 months of age (≥4)	1.30 (0.97–1.75)	0.08	1.27 (0.94–1.72)	0.12	1.15 (0.81–1.62)	0.44
Currently smoking mother (Yes)	1.00 (0.78–1.29)	0.98	1.04 (0.81–1.35)	0.74	1.54 (1.12–2.13)	0.01
Mother smoke during the child's 1st 12 months of life (Yes)	1.17 (0.88–1.55)	0.29	1.15 (0.86–1.53)	0.34	1.21 (0.86–1.71)	0.28
Parental history of atopy (Yes)	2.39 (2.21–2.57)	<0.01	2.65 (2.46–2.87)	<0.01	3.12 (2.82–3.44)	<0.01
Study period						
Study 1 (1994–1995)	Reference	Reference	Reference	Reference	Reference	Reference
Study 2 (2000–2001)	1.19 (1.08–1.31)	0.01	1.08 (0.97–1.19)	1.20	1.20 (1.06–1.36)	<0.01
Study 3 (2015–2016)	1.73 (1.57–1.91)	<0.01	1.78 (1.60–1.97)	<0.01	2.26 (1.99–2.57)	<0.01

(**c**)

|	Chronic Rash Ever (Lifetime Chronic Rash)		Chronic Rash in Last 12 Months (Current Chronic Rash)	
	Odds Ratio (95% CI)	*p*-Value	Odds Ratio (95% CI)	*p*-Value
Siblings (≤2)	1.00 (0.76–1.33)	0.99	1.02 (0.75–1.39)	0.90
Hospitalization for RTI in 1st 12 months of age (≥4)	1.46 (0.90–2.37)	0.13	1.10 (0.60–1.99)	0.76
Currently smoking mother (Yes)	1.40 (0.86–2.30)	0.18	1.36 (0.78–2.37)	0.27
Mother smoke during the child's 1st 12 months of life (Yes)	1.29 (0.77–2.16)	0.34	1.04 (0.57–1.89)	0.90
Parental history of atopy (Yes)	2.35 (2.02–2.75)	<0.01	2.35 (1.98–2.79)	<0.01
Study period				
Study 1 (1994–1995)	Reference	Reference	Reference	Reference
Study 2 (2000–2001)	0.94 (0.77–1.15)	<0.01	2.04 (0.72–1.12)	<0.01
Study 3 (2015–2016)	1.73 (1.43–2.09)	<0.01	1.83 (1.49–2.24)	<0.01

For the third survey, 11 risk factors were found to be significantly associated with the 7 primary health outcomes after multiple logistic regression. The results are shown in Table 4a,b.

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Table 4. (**a**) Basic model for the associations between risk factors and 7 health outcomes in the 3rd survey 2015–2016 by multiple logistic regression. (**b**) Basic model for the associations between risk factors and 7 health outcomes in the 3rd survey 2015–2016 by multiple logistic regression

(a)							
	Wheeze Ever (Lifetime Wheeze)		Wheeze in Last 12 Months (Current Wheeze)		Rhinitis Ever (Lifetime Rhinitis)		Rhinitis in Last 12 Months (Current Rhinitis)
	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value
Sex (Male)	1.33 (0.63–0.88)	<0.01	1.33 (1.10–1.70)	<0.01	1.39 (1.30–1.59)	<0.01	1.38 (1.30–1.61)	<0.01
Hospital admission for RTI in 1st 12 months (≥4)	1.90 (1.14–3.15)	0.01	2.14 (1.22–3.74)	0.01	1.01 (0.62–1.64)	0.97	2.16 (1.71–2.71)	0.90
RTI in last 12 months (≥4)	1.77 (1.40–2.22)	<0.01	1.85 (1.42–2.41)	<0.01	2.00 (1.57–2.54)	<0.01	2.11 (1.66–2.68)	<0.01
Currently smoking mother (Yes)	1.11 (0.68–1.80)	0.68	1.18 (0.65–7.14)	0.58	1.02 (0.67–1.56)	0.93	1.12 (0.74–1.72)	0.59
Mother smoke during the child's 1st 12 months of life (Yes)	1.82 (1.09–3.03)	0.02	2.09 (1.15–3.8)	0.01	1.29 (0.83–1.98)	0.26	1.43 (0.42–2.21)	0.11
Father smoke during the child's 1st 12 months of life (Yes)	1.17 (0.98–1.41)	0.09	1.18 (0.94–1.49)	0.14	1.23 (0.96–1.31)	0.14	1.15 (0.99–1.34)	0.08
Parental history of atopy (Yes)	2.68 (2.25–3.18)	<0.01	2.27 (1.86–2.76)	<0.01	2.47 (2.14–2.84)	<0.01	2.63 (2.28–3.03)	<0.01
Nursery school (Yes)	1.31 (1.00–1.73)	0.05	1.47 (1.08–2.00)	0.01	1.17 (0.92–1.49)	0.20	1.13 (0.89–1.44)	0.29
Given paracetamol during baby period (0–2 years) (Yes)	1.17 (0.99–1.39)	0.07	1.22 (1.00–1.49)	0.04	1.40 (1.21–1.63)	<0.01	1.33 (1.14–1.54)	<0.01
Use town gas (Yes)	1.21 (1.01–1.45)	0.03	1.14 (0.92–1.91)	0.23	1.08 (0.94–1.24)	0.25	1.17 (1.02–1.35)	0.02
Use purifier in hot and cold seasons (≥1 per week)	1.23 (1.02–1.50)	0.03	1.18 (0.94–1.48)	0.10	1.28 (1.07–1.52)	0.01	1.22 (1.02–1.45)	<0.01

RTI, respiratory tract infection

(b)					
	Current Rhinoconjunctivitis		Chronic Rash Ever (Lifetime Chronic Rash)		Chronic Rash in Last 12 Months (Current Chronic Rash)
	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value	Adjusted Odds Ratio (95% CI)	Adjusted *p*-Value
Sex (Male)	1.43 (1.25–1.67)	<0.01	1.14 (0.92–1.43)	0.24	1.25 (0.99–1.57)	0.05
Hospital admission for RTI in 1st 12 months (≥4)	1.05 (0.64–1.71)	0.84	1.30 (0.55–3.05)	0.55	1.42 (0.56–3.59)	0.46
RTI in last 12 months (≥4)	1.05 (0.64–1.71)	<0.01	1.64 (1.23–2.18)	<0.01	1.52 (1.13–2.03)	<0.01
Currently smoking mother (Yes)	1.05 (0.69–1.61)	0.83	1.19 (0.53–2.31)	0.78	1.16 (0.55–2.50)	0.69
Mother smoke during the child's 1st 12 months of life (Yes)	1.45 (0.94–2.24)	0.09	1.05 (0.50–2.18)	0.89	1.06 (0.55–2.43)	0.69
Father smoke during the child's 1st 12 months of life (Yes)	1.17 (1.00–1.37)	0.04	1.31 (1.00–2.18)	0.05	1.55 (1.17–2.07)	<0.01
Parental history of atopy (Yes)	2.66 (2.31–3.07)	<0.01	1.94 (1.58–2.37)	<0.01	1.98 (1.61–2.43)	<0.01
Nursery school (Yes)	1.15 (0.90–1.46)	0.26	1.02 (0.69–1.50)	0.9	1.00 (0.67–1.50)	0.98
Given paracetamol during baby period (0–2 years) (Yes)	1.33 (1.15–1.55)	<0.01	11.32 (1.08–1.62)	0.01	1.28 (1.00–1.61)	0.04
Use town gas (Yes)	1.18 (1.03–1.36)	0.02	11.05 (0.83–1.32)	0.69	1.29 (0.89–1.43)	0.33
Use purifier in hot and cold seasons (≥1 per week)	1.23 (1.44–1.46)	<0.01	11.11 (0.85–1.46)	0.43	1.04 (0.79–1.38)	0.73

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Of the 33 schools that participated, 6 (18%) are situated close to the main road, with a distance of 20.5 + 24.7 m, compared to all schools of 51.1 + 40 m ($p < 0.001$). There was a significant association between the distance to the main road and school PM_{10} concentration, with a correlation r = 0.214 ($p = 0.004$). The school PM_{10} level collected by the monitor correlated reasonably well with the satellite PM_{10} level ($p = 0.05$). There were significant variations in the indoor (2 sites) and outdoor (1 site) air pollutant levels, including PM_{10}, NO_2, O_3, and SO_2, at all the schools, and there was also significant variation across the schools. The overall mean concentrations of PM_{10}, NO_2, O_3, and SO_2 of the three sites collected over the 10 days for each school are depicted in Figure 1.
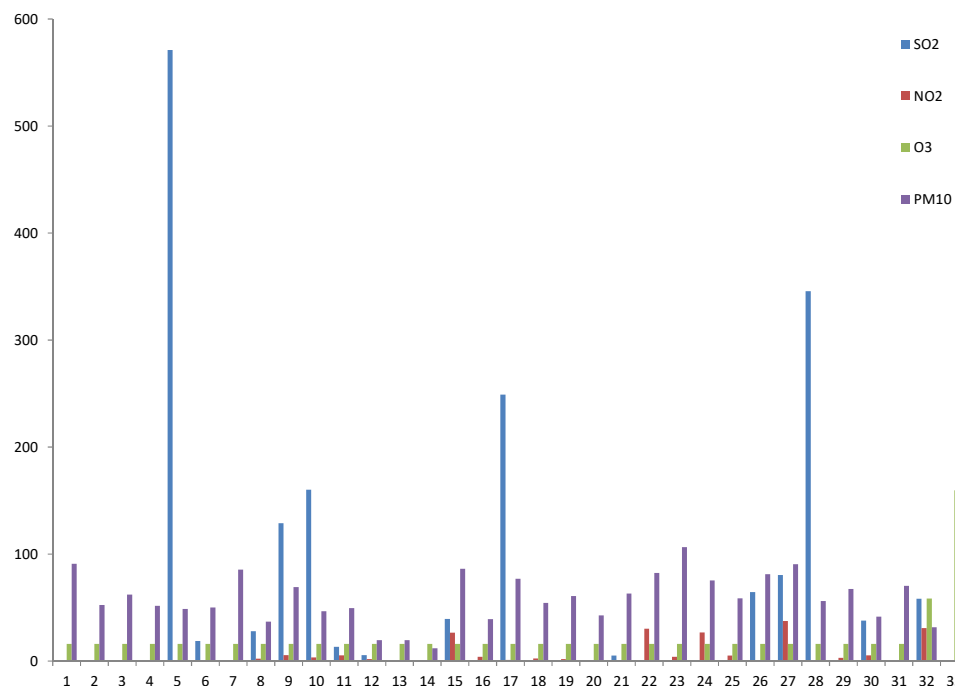
Figure 1. Overall mean concentrations of PM_{10}, NO_2, O_3, and SO_2 collected over the 10-day period for each school.

GLIMMIX multi-regression showed a significant association between school $PM_{2.5}$ and lifetime wheeze, lifetime rhinitis, current rhinitis, and current rhinoconjunctivitis, and school NO_2 and lifetime rhinitis, current rhinitis, and current rhinoconjunctivitis. There were no significant associations of school PM_{10}, O_3, SO_2, or home $PM_{2.5}$ or PM_{10} with each of the seven primary health outcomes. However, the significant associations between school $PM_{2.5}$ and NO_2 and health outcomes were lost after adjustment for multi-pollutant effects, confounding variables (significant risk factors associated with air pollutants, shown in Table 4a,b), temperature, and humidity (Table 5).

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Table 5. Results of GLIMMIX multi-regression model for the associations between air pollutants and health outcomes.

		Wheeze Ever [1] (Lifetime Wheeze)			Rhinitis Ever [2] (Lifetime Rhinitis)			Rhinitis in Last 12 Months [3] (Current Rhinitis)			Current Rhinoonjunctivitis [4]		
		Odds Ratio (95% CI)	*p*-Value	Adjusted *p*-Value *	Odds Ratio (95% CI)	*p*-Value	Adjusted *p*-Value *	Odds Ratio (95% CI)	*p*-Value	Adjusted *p*-Value *	Odds Ratio (95% CI)	*p*-value	Adjusted *p*-Value *
School	$PM_{2.5}$	1.05 (1.01–1.10)	0.04	0.28	1.05 (1.00–1.10)	0.05	0.18	1.06 (1.01–1.11)	0.04	0.13	1.06 (1.01–1.11)	0.03	0.09
	PM_{10}	1.00 (0.99–1.00)	0.33	-	1.00 (0.99–1.00)	0.95	-	1.00 (0.99–1.00)	0.89	-	1.00 (0.99–1.01)	0.87	-
	NO_2	0.99 (0.98–1.01)	0.63	-	1.01 (1.01–1.03)	0.03	0.28	1.01 (1.01–1.03)	0.04	0.28	1.01 (1.01–1.02)	0.02	0.17
	SO_2	1.00 (0.99–1.00)	0.74	-	1.00 (0.99–1.00)	0.92	-	0.99 (0.99–1.00)	0.99	-	0.99 (0.99–1.00)	0.91	-
	O_3	0.99 (0.99–1.00)	0.31	-	0.99 (0.99–1.00)	0.35	-	0.99 (0.99–1.00)	0.54	-	0.99 (0.99–1.00)	0.47	-
Residence	$PM_{2.5}$	1.00 (0.96–1.04)	0.88	-	0.99 (0.95–1.02)	0.48	-	0.99 (0.95–1.02)	0.48	-	0.99 (0.95–1.02)	0.50	-
	PM_{10}	1.00 (0.97–1.03)	0.88	-	0.99 (0.97–1.02)	0.48	-	0.99 (0.97–1.02)	0.48	-	0.99 (0.97–1.02)	0.50	-

[1] Wheeze ever (lifetime wheeze) values were adjusted with sex (male), hospital admission for RTI in 1st 12 months ($\geq$4), RTI in last 12 months ($\geq$4), mother smoke during the child's 1st 12 months of life (Yes), parental history of atopy (Yes), use town gas (Yes), use purifier in hot and cold seasons ($\geq$1 per week), and air pollutants by using multi-regression model. [2] Rhinitis ever (lifetime rhinitis) values were adjusted with sex (male), RTI in last 12 months ($\geq$4), parental history of atopy (Yes), given paracetamol during baby period (0–2 years) (Yes), use purifier in hot and cold seasons ($\geq$1 per week), and air pollutants by using multi-regression model. [3] Rhinitis values in last 12 months (current rhinitis) were adjusted with sex (male), RTI in last 12 months ($\geq$4), parental history of atopy (Yes), given paracetamol during baby period (0–2 years) (Yes), use town gas (Yes), use purifier in hot and cold seasons ($\geq$1 per week), and air pollutants by using multi-regression model. [4] Current rhinoconjunctivitis values were adjusted with sex (male), RTI in last 12 months ($\geq$4), father smoke during the child's 1st 12 months of life (Yes), parental history of atopy (Yes), given paracetamol during baby period (0–2 years) (Yes), use town gas (Yes), use purifier in hot and cold seasons ($\geq$1 per week), and air pollutants by using multi-regression model. * A significance level of $p < 0.05$ was used for all analyses. All *p*-values were not significant after adjustment for the factors in Table 4, temperature and humidity. No significant results were observed for current wheeze, lifetime chronic rash, current chronic rash, and other pollutants were not significant.

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6. Discussion

Childhood allergic diseases are a significant public health problem in all countries regardless of the level of development [10,16]. Phase I and Phase III ISAAC showed that there was an increase in the prevalence of asthma, AR, and eczema (indicated by wheeze, rhinitis, and itchy rash, respectively) in developing countries and a leveling off or decreasing trend in developed countries from the mid-1990s to the early 2000s [6,17,18]. It has been speculated that environmental and lifestyle factors that induce asthma symptoms in genetically susceptible individuals may have reached saturation level [21]. Surprisingly, our third survey showed that the prevalence of wheezing, rhinitis, and itchy rash rose again after an apparent leveling off between our first and second surveys [22,23]. The increase was especially remarkable for the prevalence of lifetime and current eczema and current rhinoconjunctivitis with almost a two-fold increase. There have been a few similar studies reported previously, but the results varied considerably, the methodology might not be consistent across the study periods, and the study spans were noticeably shorter than in our study [24–27]. A study in Poland involving four repeated cross-sectional questionnaires in children aged 7 to 10 years from 1993 to 2014 [28] showed a distinct rise in the prevalence of lifetime physician-diagnosed asthma but not for current wheeze. To our knowledge, we are the first center in developed areas to show a continual increased prevalence of wheezing, rhinitis, and itchy rash using the same ISAAC protocol and questionnaire over 21 years [6].

Our study showed a consistent increase in the prevalence of wheezing, rhinitis, and itchy rash, which are closely linked. In addition, there has been a concurrent increase in the prevalence of current symptoms suggestive of more severe diseases, including nocturnal awakenings by wheezing, nocturnal cough, and rhinitis interfering with daily activities, and being kept awake by a chronic rash. It has been suggested that diagnostic exchange may account for the increases in prevalence [29]. This was refuted in our study as the prevalence of doctor-diagnosed asthma was consistently lower than the prevalence of wheezing across the three surveys.

Since our first survey, HKSAR has experienced a series of important socioeconomic and political events. Those that might have had a direct health impact include the Bird Flu pandemic in 2001, the SARS outbreak in 2003, the implementation of comprehensive smoking-free legislation in 2007, the Flu pandemic in 2009, the zero quota policy that restricted Mainland Chinese birth in 2013, and updating Air Quality Objectives in 2014 with the implementation of a wide range of air quality improvement measures. There were more participants with small sibship sizes, which might be due to various factors, including family choice, marital postponement for women that shortens their childbearing exposure period, and economic or social circumstances. The prevalence of parents smoking during the child's 1st year of life and parental smoking at the time of the survey increased between the first and second surveys, but it seemed to level off in our third survey, possibly due to the effect of comprehensive smoking-free legislation [30]. There was an increase in the number of participants who reported frequent severe early RTI that required hospitalization in the 1st year of life. While parents with fewer children tend to be more cautious nowadays when their young child is sick, a possible increase in the incidence of young children with an inherent predisposition to more severe infection could not be excluded. In contrast, there was a decrease in frequent RTI in the last 12 months of the survey, which may reflect the general increase in public awareness about health protection from infectious diseases after several infectious epidemics.

An increased prevalence of parental history of atopy had the strongest association with the increasing prevalence of all seven health outcomes suggesting the importance of genetic predisposition. The relationship between RTI and the development of allergic diseases is intriguing. Early-life infections, especially if severe, are associated with the development of atopic disease, especially for asthma [31–33]. On the other hand, Strachan's original hygiene hypothesis proposed that a lower incidence of infection in early childhood could explain the rapid rise in allergic diseases, especially hay fever [31,34]. Our study matched both theories as we showed the increased prevalence of frequent hospitalization for RTI

in the 1st 12 months was associated with the increased prevalence of lifetime wheeze and current wheeze, while the increased prevalence of small sibship size, a surrogate for reduced microbial exposure, was associated with the increased prevalence of lifetime wheeze and current wheeze. We also noted that the increased prevalence of maternal smoking during the 1st year of a child's life was associated with an increasing prevalence of lifetime wheeze and current wheeze but not other health outcomes [35,36]. We found a study period effect associated with the prevalence change in all seven primary health outcomes with adjusted ORs ranging from 1.12 to 2.26. Our previous study and other local studies suggested that outdoor environmental pollutants have a significant impact on hospital admission for asthma and other respiratory and allergy-related diseases, as there was a rapid decline in the air quality in HKSAR associated with vibrant economic activities in the region and nearby cities including Shenzhen and Guangzhou from the 1990s [13,14]. In our third survey, we did not find a significant association between school air quality and any health outcomes after multiple logistic regression, suggesting that genetic factors (parental history of atopy), life events (RTI in last 12 months), and indoor environmental factors (maternal smoking) could be more important associative risk factors. Although 18% of the schools recruited were situated closer to the main road compared to the other schools, we failed to demonstrate an association between school air quality and any health outcomes. In USA and Canada studies, the investigators used 400 m and 75 m, respectively, to define close proximity to main roads when assessing the impacts of air pollution. All the schools included in our study would have been defined as having close proximity to main roads accordingly [37,38]. As such, our observation could be genuine due to the statutory ban against the idling of motor vehicle engines implemented in December 2011 and the updating of Air Quality Objectives in 2014 with subsequent air quality improvement measures.

Strengths and Limitations

The potential biases of the cross-sectional surveys were minimized by strict adherence to the ISAAC protocol and questionnaire. The large sample size for each survey and the summated sample size, the consistency of the results across the three surveys, the concurrent association of risk factors with the seven primary health outcomes, the narrow confidence intervals of the significant ORs, and the magnitude of the ORs of significant association matched closely with previous studies supported the belief that our methodology was robust. Some schools declined as they were worried that significant additional manpower commitment was required. Some schools were worried that if they participated in the study, their students might accidentally cause damage to air quality monitors. Due to the limited study period, we eventually recruited only 33 schools, with only 1 instead of 2 schools from 3 districts. However, we reached a sample size that provided a sufficiently large power for the study. Questions were added in our second and third surveys that were not in the first; for example, the types of fuels for cooking. Thus, we could only assess these factors if they also changed in prevalence. Due to the limited budgets, only three sets of air quality monitors were purchased. Two were placed in the classrooms, but there were usually six to eight classes for the two school years of each school. The air pollutant levels were generalized to all the other classes within the same school, potentially affecting our results. Satellite data for air pollutants were available for particulate matter but not for gaseous pollutants. Thus, our study might underestimate the health effect of residential air pollutants. We originally planned to extend the study to include more schools, but this was eventually suspended due to the emergence of the COVID-19 pandemic with school closures when we explored further research funding support.

7. Conclusions

Our study shows that the prevalences of wheezing, allergic rhinitis or rhinoconjunctivitis, and eczema have increased across three surveys. The most important associated risk factor identified was the increased prevalence of a parental history of atopy. We did

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not find school air pollutant levels to be significantly associated with the prevalence of these outcomes.

Abbreviations

AR	allergic rhinitis
CI	confidence intervals
HKSAR	Hong Kong Special Administrative Region, China
HKU/HA HKWC IRB	Institutional Review Board of the University of Hong Kong/ Hospital Authority Hong Kong West Cluster
ISAAC	International Study of Asthma and Allergies in Childhood
LSBG	Large Street Block Group
NO_2	nitrogen dioxide
O_3	ozone
OR	odds ratio
PM	particulate matter
RTI	respiratory tract infection
SD	standard deviation
SO_2	sulfur dioxide
TPU	tertiary planning unit

Appendix A

Health Questionnaire

Centre no. –

School no.

Class no. –

Please answer the following questions with 'Black ball-pen or pencil':

Date of answering the questionnaire:

　　　　　　(Day)　　　(Month)　　　(Year)

Your child's name: _____

Name of school: _____

Class _____

Child' age:

Child' date of Birth:

　　　　　　(Day)　　　(Month)　　　(Year)

Home address: _____

Contact phone no.: _____

Please answer the following questions with black ball-pen or pencil & fill up the circle (●) which is next to the appropriate answer; if there is a wrong selection, please cross out the wrong answer & fill in the appropriate answer again.

Your child is:　　　　　Boy　　　○　　　Girl　　　　○

Your child is:　　　　　Chinese　　○　　　Non-Chinese　○

If he/she is non-Chinese, please specify: _____

QUESTIONNAIRES

1. Has your child <u>ever</u> had wheezing or whistling in the chest at any time in the past?

Yes　　○　　No　　○

If you have answered "No" please skip to Question 6

2. Has your child had wheezing or whistling in the chest in the last 12 months?

Yes　　○　　No　　○

If you have answered "No" please skip to Question 6

3. How many attacks of wheezing has your child had in the last 12 months?

None　　○　　1 to 3　　○　　4 to 12　　○　　More than 12　　○

4. In the last 12 months, how often, on average, has your child's sleep been disturbed due to wheezing?

Never woken with wheezing ○

Less than one night per week ○

One or more nights per week ○

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5. In the last 12 months, has wheezing ever been severe enough to limit your child's speech to only one or two words at a time between breaths?
Yes   ○   No   ○

6. Has your child ever had asthma (doctor diagnosed)?
Yes   ○   No   ○

7. In the last 12 months, has your child's chest sounded wheezy during or after exercise?
Yes   ○   No   ○

8. In the last 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or chest infection?
Yes   ○   No   ○

9. Has your child ever had a problem with sneezing or a runny or blocked nose when he/she DID NOT have a cold or the flu?
Yes   ○   No   ○
If you have answered "No" please skip to Question 14

10. In the last 12 months, has your child had a problem with sneezing or a runny or blocked nose when he/she DID NOT have a cold or the flu?
Yes   ○   No   ○
If you have answered "No" please skip to Question 14

11. In the past 12 months, was this nose problem been accompanied by itchy-watery eyes?
Yes   ○   No   ○

12. In which of the past 12 months did this nose problem occur? (Please tick any which apply)
Jan   ○   Feb   ○   Mar   ○   Apr   ○   May   ○   Jun   ○
Jul   ○   Aug   ○   Sep   ○   Oct   ○   Nov   ○   Dec   ○

13. In the past 12 months, how much did this nose problem interfere with your child's daily activities:
Not at all   ○   A little   ○   A moderate amount   ○   A lot   ○

14. Has your child ever had hayfever?
Yes   ○   No   ○

15. Has your child ever had an itchy rash which was coming and going for at least six months?
Yes   ○   No   ○
If you have answered "No" please skip to Question 21

16. Has your child had this itchy rash at any time in the last 12 months?
Yes   ○   No   ○
If you have answered "No" please skip to Question 21

17. Has this itchy rash at any time affected any of the following places:
the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears, or eyes?
Yes   ○   No   ○

18. At what age did this itchy rash first occur?
Under 2 year   ○   Age 2–4 year   ○   Age 5 or more   ○

19. 1. Has this rash cleared completely at any time during the last 12 months?
Yes   ○   No   ○

20. In the last 12 months, how often, on average, has your child been kept awake at night by this itchy rash?
Never in the last 12 months   ○
Less than one night per week   ○
One or more nights per week   ○

21. Has your child ever had eczema (doctor diagnosed)?
Yes   ○   No   ○

22. Has your child ever had allergic rhinitis (doctor diagnosed)?
Yes   ○   No   ○

23. Was your child born in Hong Kong?
Yes   ○
No   ○   Please specific place of birth _____
           Please specific time of migration to HK _____

24. Was your child born within 3 weeks of the calculated date?

　　　Yes　　　　　　　　　　　　　○
　　No, more than 3 weeks early　　○
　　No, more than 3 weeks late　　○
　　Don't know　　　　　　○

25. What was the birthweight of your child? kg/pounds

26. How much does your child weigh recently (within 3 months)? _____ Kg or pounds
　　How tall is your child recently (within 3 months)? _____ cm

27. Was your child ever breast fed?
Yes　○　　No　○

28. How many <u>older</u> brothers or sisters does your child have? _____ brothers and sisters

29. How many <u>younger</u> brothers or sisters does your child have? _____ brothers and sisters

30. Did your child ever go to a child care facility or nursery school? (day care is defined as a child care setting where 6 or more unrelated children are present)
Yes　○　　No　○

31. Has your child had any immunizations?
Yes　○　　No　○

32. How many hospital admissions has your child had in the first 12 months of age for respiratory tract infection? (include common cold, flu, pharyngitis, acute bronchiolitis, pneumonia) _____ time (s)

33. How many times did the child require antibiotics treatment for respiratory tract infection in the first 12 months of age? _____ time (s)

34. How many respiratory tract infections has your child had in <u>the last 12 months</u>? _____ time (s)

35. How many hospital admissions has your child had <u>in the last 12 months</u> for respiratory tract infection? __ time(s)

36. We would like the child's mother/female guardian to answer the following questions. (please cross out inappropriate person)

　　a.　Have you ever had:
(i)　wheezing or whistling in the chest?　　　　Yes　○　　No　○
(ii)　asthma? (doctor diagnosed)　　　　　　　Yes　○　　No　○
(iii)　allergic rhinitis? (doctor diagnosed)　　　Yes　○　　No　○
(iv)　eczema? (doctor diagnosed)　　　　　　　Yes　○　　No　○
　　b.　Do you smoke cigarettes at all nowadays?　　　Yes　○　　No　○
If *Yes*, how many cigarettes do you smoke
　　c.　Did you smoke cigarettes during pregnancy　　Yes　○　　No　○
while you were expecting the child in our survey?
　　d.　Did you smoke cigarettes during the first year　Yes　○　　No　○
of life of the child in our survey?

37. And now the child's father/male guardian. (please cross out inappropriate person)

　　a.　Have you ever had:
(i)　wheezing or whistling in the chest?　　　　Yes　○　　No　○
(ii)　asthma? (doctor diagnosed)　　　　　　　Yes　○　　No　○
(iii)　allergic rhinitis? (doctor diagnosed)　　　Yes　○　　No　○
(iv)　eczema? (doctor diagnosed)　　　　　　　Yes　○　　No　○
b.　Do you smoke cigarettes at all nowadays?　　　Yes　○　　No　○
If *Yes*, how many cigarettes do you smoke
each day, on average while in the house.
c.　Did you smoke cigarettes during the first year　Yes　○　　No　○
of life of the child in our survey?

38. How many people living in the house smoke, including parents? _____ persons

39. Did you have the following animals in your home during the first year of life of your child?

　　　　Yes　　No
　　Dog　○　　○
　　Cat　○　　○

40. In the past 12 months, have you had the following animals in your home?

	Yes	No
Dog	○	○
Cat	○	○

41. In your house, what fuel is usually used for cooking?

	At present	During the child's first year of life
Electricity	○	○
Town Gas	○	○
Liquefied Petroleum Gas LPG	○	○
Other - please specify_____	○	○

42. In the past 12 months, how many times a week does your child engage in vigorous physical activity long enough to make him/her breathe hard?

- Never or only occasionally ○
- Once or twice per week ○
- Three to four per week ○
- Five or more per week ○

43. In the past 12 months, how often, on average, did your child eat or drink the following?

	Never or only occasionally	Once or twice per week	Most or all days
Meat (e.g., beef chicken pork)	○	○	○
Seafood (including fish)	○	○	○
Fresh fruits	○	○	○
Vegetables (green and root)	○	○	○
Pulses (peas beans lentils)	○	○	○
Cereal (including bread)	○	○	○
Pasta	○	○	○
Rice	○	○	○
Butter	○	○	○
Margarine	○	○	○
Nuts	○	○	○
Potatoes	○	○	○
Milk	○	○	○
Eggs	○	○	○
Burgers/fast food	○	○	○
Bird's nest	○	○	○
Herbal medicine	○	○	○

44. In the past 12 months, how many hours a day (24 h) during a normal week does your child watch television before and after school?

- Less than 1 h ○
- 1 to 3 h ○
- More than 3 h to 5 h ○
- More than 5 h ○

45. When your child was a baby (0–2 years) did you usually give paracetamol (e.g., Panadol, Calpol) for fever?

Yes ○ No ○

46. In the past 12 months, how often on average, have you given your child paracetamol (e.g., Panadol)?

- At least once per month ○
- At least yearly ○
- Never ○

47. What level of education have the child's parents received?

	father	mother
Primary school	○	○
Secondary school	○	○
College, university or other form of tertiary education	○	○
Never been to school	○	○

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48. Which district does your child live?

Sai Kung	○	Sha Tin	○	Tai Po	○
North	○	Islands	○	Yuen Long	○
Tuen Mun	○	Tsuen Wan	○	Kwai Tsing	○
Kwun Tong	○	Wong Tai Sin	○	Kowloon City	○
Sham Shui Po	○	Southern	○	Yau Tsim Mong	○
Eastern	○	Wan Chai	○	Central and Western	○
Mainland	○				

49. What floor does your child live on?

_____/F

50. In the past 12 months, do your child's home have the following?

	Yes	No
Air conditioning	○	○
Indoor air purifier	○	○

51. In the past 12 months, how often on average, have you turned on air conditioning?

	Hot seasons	Cold seasons
Never or only occasional	○	○
One or two days per week	○	○
Three to four days per week	○	○
Five or more days per week	○	○

52. In the past 12 months, how often on average, have you turned on indoor air purifier?

	Hot seasons	Cold seasons
Never or only occasional	○	○
One or two days per week	○	○
Three to four days per week	○	○
Five or more days per week	○	○

53. How many medium to large vehicles (excluding private car and taxi) pass through your residential street on a weekday from 6:00 to 6:05 pm?

0–20	○
21–50	○
51–100	○
More than 100	○

54. In your vehicle count in Q50, what is the approximate percentage of your residential street space was filled up with vehicles?

<25%	○
25–50%	○
51–75%	○
76–100%	○

55. On average, how much time does your child spend at home every day?

_____hours

56. On average, how much time does your child spend at school each weekday?

_____hours

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