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Geographical comparison of the prevalence of childhood asthma and allergies in Singapore

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Summary A previous study suggested that differences in the prevalence of respiratory illnesses such as asthma in school children in different regions of Singapore were not due to the influence of air pollution or environmental factors but possibly to cultural and socio-economic factors. The effects of socio-economic or demographic variables were, however, not shown in that study. In this study, we set out to discover whether regional differences in the prevalence of atopic diseases such as asthma, rhinitis and eczema in Singapore school children could be explained by different demographic profiles. The prevalence of asthma and allergies were evaluated in 6238 Singapore school children in two age groups (6–7 years [$n = 2030$] and 12–15 years [$n = 4208$]). They were from four regions, based on residential post codes. Demographic and socio-economic data were also obtained. The questionnaire of the International Study on Asthma and Allergies in Childhood (ISAAC) was used. The data showed that children residing in the northern regions of Singapore had a significantly lower prevalence of asthma and rhinitis than those in other regions. When controlled for demographic influences (age, sex and race) and socio-economic factors (type of housing), however, the differences between these regions were reduced. No geographical difference in the prevalence of eczema was observed. Thus, geographical differences in the prevalence of asthma and rhinitis in Singapore could in part be explained by demographic and socio-economic differences in the population.

Introduction

Asthma is a common cause of morbidity in Singapore children.[1,2] In a recent survey, one in five school children was reported to have chronic asthma.[3] Studies elsewhere have shown that the prevalence of atopic diseases were differentially distributed in different regions and that this was related to factors such as air pollution, the degree of industrialization, meteorological differences and proximity to roads and vegetation.[4–7] Regional differences in the prevalence of respiratory illnesses such as asthma were previously reported in Singapore.[8] There are also slight differences in the pattern of land use, meteorology and proximity to sources of pollutants and vegetation in different parts of the island,[9] although these differences are not as apparent as in larger countries. To date, land use in Singapore seems to be concentrated mostly in the central and eastern regions, while industrial estates are mainly in the west of the island.[9] The northern regions are mostly public housing estates and new towns with large areas of vegetation in the central and northern regions. The previous study suggested, however, that differences in the prevalence of respiratory illnesses in different areas of Singapore were not because of air pollution or other environmen-

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tal factors but possibly reflected cultural and socio-economic factors.[8] Demographically, households in central and eastern Singapore, where most private homes are located, have a higher income than families from the north and west who tend to be from middle or lower income groups.[10] Racially, there are more Indian and Malay families in the north.[10] Therefore, we set out to discover whether regional differences in the prevalence of diseases such as asthma, rhinitis and eczema in school children could be explained by differences in demographic profiles.

Materials and methods

Questionnaires

The ISAAC written questionnaire for asthma was identical to those used previously[3] and concentrates on past and current wheezing episodes, wheezing frequency, exercise-induced wheezing, persistent cough unrelated to respiratory infection and a doctor's diagnosis of asthma. In addition, ISAAC core questions on the presence and severity of rhinitis and eczema were also included.

The study population

Between the months of February and November 1994, we studied two age groups, 6–7 years and 12–15 years. Thirty schools from all parts of Singapore were randomly selected and 21 agreed to participate. The parents of the 6–7-year-olds were the respondents and the 12–15-year-olds completed the questionnaire themselves. The survey was conducted in English and only a small number of non-English-speaking parents required Mandarin (4.7%) or Malay (0.3%) translations.

There were 6,238 responses, approximately 90%. The demographic profile and socio-economic categories of respondents are shown in Table I according to respondents' area of residence, based on post codes. As a result of a mistake made in the initial part of the survey, 1331 6–7-year-old respondents did not receive the core questions on eczema. Responses that were excluded from analysis included 63 with invalid ($n = 17$) or missing ($n = 46$) age, and those with inconsistent answers to stem questions on asthma ($n = 218$), rhinitis ($n = 152$) and eczema ($n = 104$). As a result, the number of valid responses for asthma, rhinitis and eczema were 6,020, 6,086 and 4803, respectively.

Twenty-five (0.4%) respondents did not state their sex, and 161 (2.6%) either did not state their race or belonged to ethnic groups other than the three main ones in Singapore (Chinese, Malay and Indian). We assessed socio-economic status by asking respondents for total family income, parents' occupation(s) and type of housing (public, condominium or landed). The total family income per month was categorized as $<$ S$1000/mth, S$1000–1999/mth, S$2000–3999/mth and $>$ S$4000/mth. These categories corresponded to the bottom 16th centile, bottom 16th–43rd centile, top 24th–57th and top 24th centile, respectively, according to the Singapore population census in 1990.[10] For parental occupation, we categorized responses as both, one or no working professionals. Those with official affiliations or employed by accredited bodies, e.g. doctors, lawyers, engineers, etc., were categorized 'professionals', according to the 1990 Singapore Standard Occupational Classification. The majority of Singaporeans (approximately 80% or those with a family income of up to S$8,000 per month) live in government-built Housing Development Board (HDB) flats (public housing/flats). Those with a higher income usually own private condominiums or have landed property (terrace homes, bungalows, etc.). The response rate for family income was only 47% as most of the 12–15-year-olds who completed the questionnaire were unable to provide the information. In addition, 178 (2.9%) did not respond to the question on type of housing and 549 (8.8%) did not state the occupation of both parents. These missing data sets were excluded from the analysis.

The prevalences of asthma and allergic diseases were determined for the different regions of Singapore, which were divided into four

TABLE I. Demographic distribution of the population surveyed in different regions of Singapore

	Region (no. (%))*				
	Overall	Central	East	North	West
Overall	6560	1600	1730	1441	1786
Age group†					
6–7 yrs	2354 (36)	342 (21)	788 (46)	792 (55)	431 (24)
12–15 yrs	4206 (64)	1258 (79)	942 (54)	649 (45)	1355 (76)
Sex					
Male	3541 (54)	788 (49)	1094 (63)	744 (52)	913 (51)
Female	2993 (46)	811 (51)	631 (36)	683 (47)	867 (49)
Race‡					
Chinese	5202 (79)	1352 (85)	1485 (86)	1002 (70)	1360 (76)
Malay	890 (14)	143 (9)	165 (10)	271 (19)	311 (17)
Indian	307 (5)	70 (4)	43 (2)	120 (8)	74 (4)
Type of housing†					
Public flats	4885 (74)	1045 (65)	1180 (68)	1131 (78)	1526 (95)
Private condo.	599 (9)	221 (14)	195 (11)	50 (3)	133 (7)
Landed house	816 (12)	262 (16)	300 (17)	174 (12)	80 (4)
Household income†					
$<$ 1K/mth	267 (4)	32 (2)	32 (2)	126 (9)	77 (4)
$\geqslant$ 1–$<$ 2 K/mth	872 (13)	138 (9)	121 (7)	325 (23)	287 (16)
$\geqslant$ 2–$<$ 4K/mth	1079 (16)	223 (14)	257 (15)	281 (20)	318 (18)
$\geqslant$ 4 K/mth	981 (15)	256 (16)	430 (25)	128 (9)	166 (9)

*The total number (and percentages) do not add up to the overall owing to some missing data which were excluded from analysis; †χ^2 test, $p < 0.001$ comparing demographic distribution of the study population by region; ‡minority races, which make up approximately 1% of the Singapore population were excluded.

main regions, northern/north-eastern, eastern, western and central, based on the residential post codes given. The north and north-eastern regions (referred to hereafter as northern) were combined because they are made up mainly of public housing estates and new towns. Those without post codes (missing data) and those residing in areas bordering two regions (i.e. post codes not within those listed) were excluded.

Statistical analysis

The data were initially analysed by cross-tabulation and evaluated where appropriate, using the χ^2 or Fisher's exact test. Further statistical analyses were performed by computation of the prevalence ratios (PRs) and 95% confidence intervals (95% CI) via the modified Cox proportional hazard regression model, with assumption of a constant risk period. Multiple regression analysis was used to control for potentially confounding factors, in particular demographic (age, sex and race) and socio-economic factors. However, owing to the high proportion of missing data for 'total family income' and to avoid problems associated with collinearity, only 'type of housing' was used as a socio-economic variable in the regression model. Procedures from the SAS software package version 6.08 were used.[11]

Results

Table II shows the cumulative and current prevalence of wheezing, doctor-diagnosed 'asthma' and asthma-like symptoms (wheez-

TABLE II. Prevalence of childhood asthma, rhinitis and eczema by region

	Region (no. (%))				
	Overall	Central	East	North	West
Asthma					
Ever wheezed	21.3	24.5	23.5	13.4	20.7†
Wheezed in last 12 mths	12.1	14.1	12.8	8.9	11.4†
Doctor-diagnosed asthma	20.5	23.9	18.9	14.3	22.4†
Any asthma symptoms⋆, ever	30.5	33.7	33.2	23.3	29.1†
Asthma symptoms⋆ in last 12 mths	23.6	25.9	25.3	19.0	22.4†
Rhinitis					
Ever had symptoms of runny nose	43.0	45.2	43.1	32.2	47.4†
Runny nose in last 12 mths	36.4	39.3	36.6	26.8	39.1†
Doctor-diagnosed hay fever	4.8	4.8	4.9	6.2	3.8†
Allergic rhinitis‡ in last 12 mths	22.6	25.6	22.3	16.8	23.5†
Eczema					
Ever had rashes	10.4	11.4	9.3	9.6	10.8
Rashes in last 12 mths	9.3	10.4	9.4	8.4	9.1
Doctor-diagnosed eczema	3.9	5.4	1.4	4.5	3.5†
Eczema symptoms§ in last 12 mths	7.3	7.9	7.3	6.3	7.3

⋆ Asthma symptoms: a positive response to wheeze, nocturnal cough or exercise-induced wheeze; † χ^2 test, $p < 0.05$ comparing prevalence of atopic diseases and symptoms by region; ‡ allergic rhinitis symptoms: a positive response to having symptoms of blocked/runny nose or sneezing apart from 'flu, associated with itchy eyes or seasonal symptoms; § eczema symptoms: a positive response to having chronic rashes with typical distribution or early onset (before 5 years of age).

ing, cough wheezing, exercise wheezing), symptoms of rhinitis and doctor-diagnosed 'hay fever', and symptoms of rashes and doctor-diagnosed 'eczema' in the different regions of Singapore. Significant differences in prevalence were found in each of the asthma parameters analysed. However, owing to significant differences in the distribution between regions of the population surveyed (see Table I), multiple regression models controlling for demographic differences (age, sex, race and type of housing) were used for analysis. Prior to controlling the confounding demographic factors, significant geographical differences were found (see Table III, unadjusted relative risk). The northern regions of Singapore had significantly lower asthma prevalences than central, eastern and western. After controlling for demographic factors, however, the differences were reduced or became statistically not significant.

As with asthma, significant geographical differences in the prevalence of rhinitis were found. Again, the northern regions of Singapore had significantly lower prevalences of reported symptoms of rhinitis than other regions but a higher rate of reported diagnosis of 'hay fever'. However, when controlled for the influence of demography (age, sex, race and type of housing), the differences between these regions were reduced, indicating once more that geographical differences could be explained by the demographic profile of the population.

Unlike asthma and rhinitis, there were no geographical differences in the prevalence of eczema symptoms. Doctor-diagnosed eczema, however, was less prevalent among school children in the east (12/866, 1.4%) than elsewhere (prevalence ranging between 3.5% and 5.7%). This difference remained statistically significant even after controlling for the

TABLE III. Prevalence of asthma, rhinitis and eczema and related symptoms by multiple Cox's proportional hazard regression

		Region (prevalence ratio (95% confidence interval))		
		Central	Eastern	Western
Asthma				
Ever wheezed	unadj.	1.36 (1.24–1.49)*	1.31 (1.20–1.44)*	1.18 (1.08–1.30)*
	adj.	1.24 (1.08–1.41)*	1.15 (1.00–1.31)*	—
Wheezed in last 12 mths	unadj.	1.27 (1.13–1.42)*	1.18 (1.04–1.32)*	—
	adj.	—	—	—
Doctor-diagnosed asthma	unadj.	1.33 (1.21–1.46)*	1.10 (1.00–1.20)*	1.25 (1.14–1.38)*
	adj.	1.16 (1.06–1.28)*	1.11 (1.01–1.22)*	—
Any asthma symptoms, ever	unadj.	1.25 (1.16–1.36)*	1.24 (1.14–1.35)*	1.10 (1.01–1,19)*
	adj.	1.20 (1.06–1.35)*	1.15 (1.02–1.30)*	1.13 (1.00–1.27)*
Asthma symptoms in last 12 mths	unadj.	1.20 (1.10–1.31)*	1.17 (1.07–1.28)*	1.26 (1.10–1.45)*
	adj.	1.30 (1.13–1.49)*	—	—
Rhinitis				
Ever had symptoms of runny nose	unadj.	1.26 (1.16–1.35)*	1.20 (1.11–1.29)*	1.33 (1.24–1.44)*
	adj.	—	1.15 (1.02–1.31)*	1/15 (1.01–1.29)*
Runny nose in last 12 mths	unadj.	1.27 (1.18–1.38)*	1.19 (1.10–1.29)*	1.27 (1.17–1.38)*
	adj.	—	—	1.14 (1.00–1.29)*
Doctor-diagnosed hay fever	unadj.	—	—	0.77 (0.64–0.91)*
	adj.	—	—	—
Allergic rhinitis in last 12 mths	unadj.	1.27 (1.16–1.39)*	1.13 (1.03–1.24)*	1.18 (1.08–1.29)*
	adj.	—	1.17 (1.02–1.35)*	1.14 (1.00–1.31)*
Eczema				
Ever had rashes	unadj.	—	—	—
	adj.	—	—	—
Rashes in last 12 mths	unadj.	—	—	—
	adj.	—	—	—
Doctor-diagnosed eczema	unadj.	—	0.67 (0.53–0.85)*	—
	adj.	—	0.60 (0.47–0.78)*	—
Eczema symptoms in last 12 mths	unadj.	—	—	—
	adj.	—	—	—

* $p < 0.05$; unadjusted: influence of the region on the dependent variable not controlled for demographic factors; adjusted: influence of the region on the dependent variable controlled for demographic (age, sex and race) and socio-economic factors (type of housing); reference category for region: North; type of housing was the only socio-economic variable included in the model to avoid problems associated with collinearity.

influence of demographic and socio-economic factors (Table III).

Discussion

There are wide geographical differences in asthma prevalence worldwide. These differences may sometimes be due to the different population groups studied and at other times ascribed to the different climatic and environmental conditions prevailing. The prevalence of asthma in industrialized countries tends to be higher than in non-industrialized or developing countries. The reported prevalence of 'current' or active asthma in children in industrialized countries currently ranges between 10% and 30% and between 5% and 15% in non-industrialized or developing countries.[12] The increase in the incidence of asthma in under-developed nations has been ascribed to the influence of and contact with the western world, as in Papua New Guinea,[13] and to rapid urbanization, as in Singapore.[3]

Differences were observed in the prevalence

of asthma in different regions of Singapore. The northern regions had a significantly lower asthma prevalence than other regions. Factors suggested to explain geographical differences in other countries include weather conditions and air pollution.[14,15] Different weather patterns are unlikely to cause variations in our population. Singapore is approximately 80 km from the equator and has evenly high temperatures and relative humidity throughout the year.[9] The only likely meteorological variation between regions would be rainfall. The north-central regions have higher rainfall than the coastal regions. This could influence the overall aerobiological burden of pollen and spores in different regions as rainfall has been shown to influence the aerobiological spore-load in our local environment.[16] This may in turn have an influence on the prevalence of asthma.

Land-use patterns and close proximity to industrial estates are other possible explanations for such differences. In Singapore, land use is mainly in the central and eastern regions, while industrial estates are mainly in the west.[9] The northern and north-eastern regions are mainly public housing estates and new towns. The west has also been recording slightly higher absolute ambient air pollutant levels (particularly for suspended particulates and sulphur dioxides) than the rest of Singapore but these levels are not significant (1990–1994 levels).[17] This profile suggests a possible association between development and asthma prevalence. Air pollution has been reported to be the link between development and increased asthma prevalence.[18] It has also been shown to be associated with severe asthma attacks and aggravated atopic disorders.[17,19,20] A previous study in Singapore compared the prevalence of respiratory illnesses in school children in industrial, urban and rural areas and ruled out the influence of air pollution. The authors maintained that varying air pollution levels in Singapore were well within the long-term standards set by the World Health Organization and concluded that differences in respiratory symptom prevalence might be owing to cultural and socio-economic variables.[8] In the current study, the differences between regions in asthma prevalence were observed to have narrowed or become insignificant after controlling for demographic factors. This indicates that geographical differences could partly be explained by demographic differences. In addition, the mobility of the population over time into different regions may have masked the effects of each variable analysed and must be taken into consideration. Our previous study also showed that a higher prevalence of wheezing and rhinitis was associated with higher socio-economic status.[3] Thus, one would expect a higher prevalence of asthma and rhinitis in central and eastern regions where a greater proportion of the population has a higher income.[10]

The prevalence of hay fever varies within and between countries.[12] In Britain, the prevalence of self-reported hay fever in children was 14.1% in Scotland but rose to 20% in south-east England.[21] Another study showed that the proportion of patients consulting for hay fever declined from the north to the south of England and Wales.[22] In Australia, the lifetime prevalence of hay fever in children aged 8–10 years was reported to be significantly higher in dry, inland areas than in damp, coastal ones.[23] Worldwide prevalence figures in school children appear to be lower in Europe than in America.[12] A study of the adult Singapore population noted higher prevalences in three of five housing estates surveyed[24] and also found significant geographical differences in the prevalence of rhinitis in children.

Geographical variations in prevalence have been attributed partly to differences between regions in the type, relative potency and overall aerobiological burden of pollen and spores. Ragweed pollen, for instance, the most common aero-allergen in America, is believed to be more potent than the grass and tree pollen associated with hay fever in Europe.[25] In Australia, differences between coastal and inland areas have been attributed to the higher aero-allergen burden inland.[23] Whether this explains geographical differences in the prevalence of rhinitis in Singapore requires further evaluation. The aerobiological profiles in different regions of Singapore seem to be

very similar, although heavier spore loads were observed in areas near dense vegetation (mainly in the central region) than in highly urbanized areas.[16]

In some populations, hay fever appears to be more prevalent in urban than in rural communities,[26] but the reason is not known. Possible explanations include the preferential migration of individuals with hay fever from rural to urban areas to reduce exposure to grass and pollen, or it might be that higher pollution in urban areas exacerbates the allergic response, thereby increasing the prevalence of hay fever in these areas.[27] In Japan, it was shown that cedar pollen sensitivity was higher among residents in heavily polluted areas.[27] In Southeast Asia, however, a study comparing the prevalence of asthma, allergy and atopy in three populations concluded that, although considerable differences exist in the prevalence of asthma and allergic diseases, they were more associated with family history than with atopy.[28] This suggests that in that region genetic and environmental factors common to the family, other than aeroallergen sensitization or air pollution, are more important in the pathogenesis of asthma and allergy.[28] When geographical differences were controlled for the influence of demographic factors in this study, the differences between regions were reduced and became statistically not significant, indicating that the differences could be explained by factors inherent in the demographic profile of the population.

With eczema, geographical variations in prevalence in children have been described in Britain and were noted to match closely the regional variations in hay fever.[22] In Singapore, however, unlike the distribution of asthma and rhinitis, no geographical differences were found in the prevalence of eczema. Doctor-diagnosed eczema, however, was less prevalent in the eastern region than elsewhere, and this difference remained statistically significant even after controlling for the influence of demographic and socio-economic factors. Thus, unlike asthma and rhinitis, the geographical distribution of eczema may not be associated with the demographic profile of Singapore.

Studies on children whose parents have migrated from developing to developed countries suggest that eczema is associated with urbanization and with development within those industralized countries.[29] Valid deductions, however, can hardly be made from the few reports worldwide and the very few from developing and non-Caucasian populations. Nevertheless, it seems that the pattern of genetic predisposition, prevalence, and sex distribution of eczema in developing countries is different from that in industralized nations.

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