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Differing asthma prevalence by gross national index of country of birth among New York City residents

M. Chang & E. A. Kelvin

Epidemiology & Biostatistics Program, CUNY School of Public Health, Hunter College, New York, NY, USA

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Correspondence

Elizabeth A. Kelvin, Epidemiology & Biostatistics Program, CUNY School of Public Health, Hunter College, 2180 Third Avenue, New York, NY 10035, USA.
Tel.: 212-396-7751
Fax: 212-396-7644
E-mail: ekelvin@hunter.cuny.edu

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Abstract

Background: The hygiene hypothesis suggests that higher exposure to infectious agents may be one reason for regional differences in asthma. This would suggest that immigrants from less developed countries, where infections are more common, to highly developed countries will have lower risk of asthma compared with natives, as has been found in a number of studies. We expand the research on immigrants to look at the level of development in country of origin as a predictor of asthma in New York City residents.

Methods: Data came from the 2009 cross-sectional Community Health Survey. We used logistic regression to assess the relationship of country of birth and the gross national income (GNI), an indicator of the level of development, of country of birth with asthma among immigrants and US-born New York City residents.

Results: Those who were foreign born had lower odds of having asthma compared with those US born (OR = 0.43, $P < 0.001$). There was a dose relationship between GNI and asthma with decreasing odds of having asthma associated with lower GNI in country of birth (low GNI country: OR = 0.26, $P = 0.014$; middle GNI country: OR = 0.36, $P < 0.001$; and high GNI country = reference).

Conclusions: These findings lend support to the hygiene hypothesis in that the odds of having asthma among New York City residents was lowest among people born in the least developed countries, as indicated by GNI, where infections are likely the most common.

The hygiene hypothesis posits that modern sanitation and health care have reduced exposure to infectious agents, altering the human immune system to respond inappropriately to allergens. As expected from this hypothesis, recent increases in allergic diseases, such as asthma, have coincided with the decreases in prevalence of infectious diseases (1). Studies have found that children growing up in farm areas have fewer allergic disorders compared with those growing up in urban environments (2–4). Having more siblings was also found to have a protective effect from atopy (5). Exposure to orofecal pathogens endemic in Africa and Latin America was found to be associated with lower risk of atopy (6). Furthermore, an ecological study found a positive association between country-level income, a possible indicator for exposure to infections, and prevalence of allergy symptoms among school children (7). Taken together, research suggests that lower exposure to infectious agents may be one reason behind the increased risk of asthma.

In countries with rising prevalence of asthma, allergic respiratory diseases are higher in urban areas (8). In addition to decreasing exposure to infectious pathogens, urban living is associated with asthma risk factors, such as traffic, car exhaust, tobacco smoke, and air pollutants (8). We see this in the United States (USA), with urban communities having higher recorded prevalence of asthma (9).

Several studies conducted in urban settings have found differences in asthma between native and foreign born individuals living within the same communities. An Israeli study found that Ethiopian immigrants had decreased asthma prevalence at age 17 compared with those who were Israel born (10). Similar findings were reported for Asian immigrants in Australia (11), Albanian immigrants in Milan (12), and Mexican immigrants in the USA (13). Because immigrants have different early-life exposures to infectious agents compared with their nonimmigrant counterparts, these immigrant-native comparisons can provide additional evidence to

support the hygiene hypothesis. However, because not all immigrants come from developing countries, we would expect that the protective effect of being foreign born among those living in a high-income country would only apply to those born in low-income countries. Thus, analyses comparing the risk of asthma between residents by the level of development of their birth country could provide additional evidence for or against the hygiene hypothesis.

New York City (NYC) has a diverse immigrant population, with immigrants from countries with varying levels of development. Comparing asthma prevalence between NYC residents by the income level of their country of birth will allow us to explore whether native-immigrant differences in asthma could be due to early-life exposure to environments specific to underdevelopment, that is, early-life exposure to infections.

Methods

Study description

We used data from the 2009 NYC Community Health Survey (CHS) (14), a yearly telephone survey developed by the NYC Department of Health and Mental Hygiene that collects data on the health of New Yorkers by selecting a stratified random sample of residents to produce neighborhood and citywide estimates. Strata were defined using the United Hospital Fund's neighborhood designations (15). The response (proportion contacted and deemed eligible plus those selected but unable to contact who participated) and cooperation rate (proportion successfully contacted and deemed eligible who participated) for the 2009 CHS were 34% and 87%, respectively, for landlines and 46% and 96%, respectively, for cell phones. This study includes data from 9 934 adults aged 18 years and older from all five boroughs.

Asthma definition

Asthma was defined based on self-report by the participant that he/she had been told by a doctor, nurse, or other health professional that he/she has asthma.

Country of birth

Country of birth was examined in two ways. First, an indicator was created for foreign born (*vs* US born). Second, income level of country of birth was categorized in accordance with World Bank's country income classification system for 1997, 2002, and 2010, using the years that were closest to the estimated date of arrival in the USA based on reported length of stay in USA (16). A low-income country was defined as one with \$785 or less Gross National Income (GNI) per capita for participants living in the USA 10 or more years (1997 data), \$735 or less for participants living in the USA 5–9 years (2002 data), or \$1005 or less for participants living in the USA <5 years (2010). A middle-income country was one with \$786–\$9643, (1997), \$736–\$9075 (2002), or \$1006–\$12 275 (2010) GNI per

capita, and a high-income country was one with \$9655 (1997), \$9075 (2002), or \$12 276 (2010) or more GNI per capita. Those born in the USA were included in the high-income category.

Data analysis

Demographic characteristics (race, gender, age), country of birth, length of time in the USA (US born categorized as 10 or more years), borough of residence, socioeconomic characteristics (education, income), health indicators (hypertension and exercise), and literature-cited asthma risk factors (smoking status, second-hand smoke exposure, measures of exposure to air pollution: having heard about air pollution level being abnormally high (bad air warning) through local media and reporting hearing excessive traffic noise at home) (8, 17) were described for the total sample and by asthma status. The statistical significance of associations between the independent variables and asthma was assessed using the chi-square test.

Simple logistic regression was utilized to evaluate the crude association between asthma and the country of birth measures. Multivariate logistic regression models were then used to adjust for potential confounders.

Those with missing values for any of the variables included in a regression model were excluded from that model. This led to a sample of $N = 9860$ for the unadjusted US born *vs* foreign born model, which changed to 8867 for the adjusted model, and $N = 9628$ for the unadjusted country of birth by GNI per capita model, which changed to 8708 for the adjusted model. SAS version 9.0 (SAS Institute, Cary, NC, USA) was used for all analyses, which were weighted to the NYC population and adjusted for the complex sampling method. Statistical significance of associations was assessed by a P -value of <0.05 .

Results

Descriptive statistics

Table 1 shows the descriptive statistics. Eleven percent of the population had asthma. Approximately 57.9% were born in the USA, 69.4% were born in a high-income country, 29.5% in a middle-income country, and 1.1% in a low-income country. Approximately 94.5% had been in the USA for 10 years or longer, 3.2% for 5–9 years, and 2.2% for <5 years. Fifty-four percent of the population was female. Approximately 45.1% were aged 24–44, 28% were 45–64, 15.4% were 65 and older, and 11.5% were 18–24 years old. Most were non-Hispanic white (38.8%), 25.6% were Hispanics, 23.2% were black, 10.2% were Asian/Pacific Islander, and 2.3% were other race. Approximately 41.9% were college graduates, 21.9% had some college/technical school education, 31% were high school graduates, and 13.3% had not graduated from high school. Most lived in Brooklyn (29.7%) or Queens (28.6%), 21% resided in Manhattan, 15.3% in the Bronx, and 5.4% in Staten Island. Approximately 24.7% earned <100% of the federal poverty level line (FPL), 21.7% earned

Table 1 Sociodemographic characteristics and asthma risk factors of the study population by asthma status

Variable	Total	%	Asthma	% with asthma	No Asthma	% without asthma	P-value (chi-square)
US* born/foreign born	9860		1121	11.4	8739	88.6	<0.001
US born	5708	57.9	843	14.8	4865	85.2	
Foreign born	4152	42.1	278	6.7	3874	93.3	
Country GNI† per capita	9666		1139	11.8	8527	88.2	
Low-income country(<\$1006)	108	1.1	4	3.7	104	96.3	<0.001
Middle-income country (\$1006–12 275)	2849	29.5	199	7.0	2650	93.0	
High-income country (>\$12 275)	6709	69.4	936	14.0	5773	86.0	
Length of time in the USA (foreign born)	9838		1157	11.8	8681	88.2	0.030
<5 years	223	2.2	15	6.7	208	93.3	
5–9 years	314	3.2	9	2.9	305	97.1	
10+ years	9301	94.5	1133	12.2	8168	87.8	
Age group	9884		1122	11.4	8762	88.6	<0.001
18–24	1132	11.5	191	16.9	941	83.1	
24–44	4460	45.1	465	10.4	3995	89.6	
45–64	2766	28.0	312	11.3	2454	88.7	
65+	1526	15.4	154	10.1	1372	89.9	
Sex	9911		1122	11.3	8789	88.7	<0.001
Male	4578	46.2	430	9.4	4148	90.6	
Female	5333	53.8	692	13.0	4641	87.0	
Race	9811		1024	10.4	8787	89.6	<0.001
White	3807	38.8	249	6.5	3558	93.5	
Black	2277	23.2	335	14.7	1942	85.3	
Hispanic	2508	25.6	347	13.8	2161	86.2	
Asian/Pacific Islander	996	10.2	62	6.2	934	93.8	
Other	223	2.3	32	14.3	191	85.7	
Education	10637		1120	11.4	9517	96.6	<0.001
Less than high school	1306	13.3	199	15.2	1107	84.8	
High school graduates	3049	31.0	233	7.6	2816	92.4	
Some college/tech school	2158	21.9	323	15.0	1835	85.0	
College grad	4124	41.9	365	8.9	3759	91.1	
Borough of residence	9908		1123	11.3	8785	88.7	<0.001
Bronx	1514	15.3	244	16.1	1270	83.9	
Brooklyn	2943	29.7	283	9.6	2660	90.4	
Manhattan	2078	21.0	233	11.2	1845	88.8	
Queens	2834	28.6	310	10.9	2524	89.1	
Staten Island	539	5.4	53	9.8	486	90.2	
Bad air warning	9439		1077	11.4	8362	88.6	0.040
Yes	2259	23.9	299	13.2	1960	86.8	
No	7180	76.1	778	10.8	6402	89.2	
Disrupted by traffic noise	9714		1103	11.4	8611	88.6	0.440
Yes	2110	21.7	255	12.1	1855	87.9	
No	7604	78.3	848	11.2	6756	88.9	
Exercise	9902		1121	11.3	8781	88.7	0.510
Yes	7230	73.0	832	11.5	6398	88.5	
No	2672	27.0	289	10.8	2383	89.2	
High blood pressure	9895		1122	11.3	8773	88.7	0.002
Yes	2670	27.0	367	13.7	2303	86.3	
No	7225	73.0	755	10.4	6470	89.6	
Smoking	9854		1118	11.3	8736	88.7	0.100
Never	6150	62.4	681	11.1	5469	88.9	
Current	1576	16.0	215	13.6	1361	86.4	
Former	2128	21.6	222	10.4	1906	89.6	
Second-hand smoker in home	8740		987	11.3	7753	88.7	0.510
Yes	1036	11.9	152	14.7	884.0	85.3	
No	7704	88.1	835	10.8	6869	89.2	

Table 1 (Continued)

Variable	Total	%	Asthma	% with asthma	No Asthma	% without asthma	P-value (chi-square)
Income (% FPL‡)	7342		938	12.8	6404	87.2	0.330
<100% FPL	1812	24.7	235	13.0	1577	87.0	
100–200% FPL	1595	21.7	203	12.7	1392	87.3	
200–400% FPL	1513	20.6	177	11.7	1336	88.3	
400–600% FPL	1414	19.3	146	10.3	1268	89.7	
>600% FPL	1008	13.7	177	17.5	831	82.5	

*US, United States.

†GNI, Gross National Income.

‡FPL, Federal Poverty Level.

100–200%, 20.6% earned 200–400%, 19.3% earned 400–600%, and 13.7% earned >600% FPL. Most of the population had not seen any signs for bad air warning (76.1%), were not disrupted by traffic noise at home (78.3%), exercised regularly (73%), did not have hypertension (73%), never smoked (62.4%), and were not exposed to second-hand smoking at home (88.1%).

US-born participants were more likely to have asthma (14.8%) than those who were foreign born (6.7%) ($P < 0.001$). Those born in high-income countries were more likely to have asthma (14.0%) compared with those born in a middle- (7.0%) or low-income countries (3.7%) ($P < 0.001$). Participants living in the USA 10 or more years were more likely to have asthma (12.2% vs 2.9% and 6.7%, among those in the USA 5–9 years and 5 years, respectively, $P = 0.030$). Those in the youngest age group (18–24 years) had the highest prevalence of asthma (16.9% vs 10.1–11.3% for other age groups, $P < 0.001$). Those who were black (14.7%), Hispanic (13.8%), or other race (14.3%) were more likely to have asthma compared with those who were white or Asian/Pacific Islander (6.5% and 6.2%, respectively; $P < 0.001$). Women were more likely to have asthma (13% vs 9.4%; $P < 0.001$), as were those who lived in the Bronx (16.1% vs 9.6–11.2% for all other boroughs; $P < 0.001$). Those who had not graduated from high school had the highest prevalence of asthma (15.2% vs 7.6–15% for all other education categories; $P < 0.001$). Those who had noted bad air warning signs (13.2% vs 10.8%; $P = 0.040$), and those with high blood pressure (13.7% vs 10.4%, $P = 0.002$) also had higher asthma prevalence.

Logistic regression models

In the univariate model, those who were foreign born had lower odds of having asthma than those born in the USA (odds ratio (OR) = 0.41, $P < 0.001$) (Table 2). Those who were from low- (OR = 0.22, $P = 0.005$) and middle-income countries (OR = 0.39, $P < 0.001$) had lower odds of having asthma compared with those who were born in high-income countries (Table 3).

After adjusting for potential confounders, those who were foreign born still had significantly lower odds of having

asthma than those born in the USA (OR = 0.43, $P < 0.001$) (Table 2). Those who were from low- and middle-income countries also had lower odds of having asthma than those born in a high-income country (low-income country OR = 0.26, $P = 0.014$; middle-income country OR = 0.36, $P < 0.001$) (Table 3). In the adjusted models, we saw that those who had resided in the USA 5–9 years had lower odds of having asthma than those who resided in the USA 10 or more years (US-born model OR = 0.18, $P = 0.002$, GNI model OR = 0.18, $P = 0.003$).

Discussion

We found that country of birth was a significant predictor of asthma status among New Yorkers. As in previous studies (10–13), those who were foreign born had lower odds of asthma than those born in the USA. Furthermore, those who were born in low-income countries, as measured by GNI per capita, had the lowest odds of having asthma, followed by those from middle-income countries compared with those from high-income countries in a dose–response relationship with GNI per capita of country of birth. Both findings are maintained after adjusting for a number of possible confounders.

Our findings are consistent with the hypothesis that economic development is associated with increases in allergic disorders such as asthma (1). The biologic mechanism hypothesized to link economic development and asthma is the decrease in infection exposure from improvements in sanitation and health infrastructure, leading to alterations in the development of the immune system (1). Infectious agents contain components (pAMPs) able to interact with molecular structures present on cells that elicit Th1 responses (18). Allergens, lacking the typical pAMPs, will induce Th2 responses as the default pathway (1), the pathway involved in allergic disorders (1, 18). Consistent with this idea is the low prevalence of allergic disorders among children living in less developed regions with high rates of intestinal pathogens (19, 20) as well as children exposed to farms and those who have more siblings (5). In the experimental realm, administration of microbial parts suppressed hallmark allergy responses (1).

Table 2 Unadjusted and adjusted logistic regression models comparing the odds of having asthma by country of birth (US vs non-US born)

	<i>n</i>	OR (95% CI)	<i>P</i>
Unadjusted model			
US*/foreign born			
US born	9860	1	–
Foreign born		0.41 (0.33; 0.52)	<0.001
Adjusted Model			
US*/foreign born			
US born	8867	1	–
Foreign born		0.43 (0.32; 0.56)	<0.001
Sex			
Female		1	–
Male		0.68 (0.54; 0.85)	0.001
Borough			
Brooklyn		1	–
Bronx		1.41 (1.05; 1.90)	0.024
Manhattan		1.29 (0.92; 1.81)	0.136
Queens		1.32 (0.98; 1.79)	0.071
Staten Island		1.14 (0.79; 1.64)	0.477
Race			
White		1	–
Black		1.64 (1.23; 2.19)	0.001
Hispanic		1.75 (1.28; 2.39)	0.001
Asian/Pacific Islander		1.05 (0.64; 1.73)	0.846
Other		1.76 (0.84; 3.70)	0.134
Length of time in the USA			
10+ years		1	–
<5 years		1.00 (0.42; 2.45)	0.985
5–9 years		0.18 (0.06; 0.55)	0.002
Education			
College grad		1	–
Did not graduate high school		1.64 (1.12; 2.39)	0.011
High school graduate		0.91 (0.66; 1.25)	0.559
Some college/technical school		1.36 (1.02; 1.82)	0.037
Age			
65+		1	–
18–24		2.17 (1.32; 3.55)	0.002
24–44		1.46 (1.06; 2.03)	0.022
45–64		1.35 (1.01; 1.79)	0.040
Income (%FPL†)			
<100% FPL		1	–
100–200% FPL		1.02 (0.75; 1.38)	0.915
200–400% FPL		0.96 (0.69; 1.33)	0.791
400–600% FPL		0.84 (0.59; 1.20)	0.340
>600% FPL		0.96 (0.67; 1.31)	0.694
Smoking status			
Never		1	–
Current		1.13 (0.86; 1.48)	0.381
Former		0.98 (0.76; 1.27)	0.890
Exposure to second-hand smoke			
No		1	–
Yes		1.10 (0.80; 1.52)	0.559
Bad air warning signs			
Did not see		1	–
Did see		1.26 (1.01; 1.58)	0.043
Disrupted by traffic noise at home			

Table 2 (Continued)

	<i>n</i>	OR (95% CI)	<i>P</i>
No		1	–
Yes		1.04 (0.81; 1.34)	0.742
High blood pressure			
No		1	–
Yes		1.54 (1.20; 1.96)	0.001
Exercise regularly			
No		1	–
Yes		1.09 (0.87; 1.36)	0.467

*US, United States.

†FPL, Federal Poverty Level.

However, it appears that not all infections are protective. Respiratory infections such as respiratory syncytial virus (21) and rhinovirus (19) are thought to induce respiratory tract damage, predisposing those individuals to respiratory symptoms later in life. Other infections, especially orofecal pathogens such as hepatitis A and *Toxoplasma gondii*, show an inverse relationship with atopic sensitization and asthma (19). These findings suggest that ingested microbes at mucosal surfaces may educate our immune system (21), and respiratory infections do not.

As expect, those who have lived in the USA 5–9 years had significantly lower asthma prevalence compared with those who had been in the USA for longer than 10 years, but, unexpectedly, this was not seen among those who had been in the USA < 5 years. In direct contrast, an Israeli study found that the longer immigrants lived in Israel, the higher their probability of having asthma (10). It may simply be that the number of participants in the < 5 years group was too small to detect a significant difference, but this finding may also point to how changes in American immigration policies may change the nationality make-up of the immigrant population from year to year.

There were several limitations to our study. Although we adjusted for length of time in the USA and classified income level of country of birth according to length of time in the USA, because this dataset does not measure specific length of time spent in the country of birth, it is unknown whether the environmental differences associated with country of birth is truly a relevant factor and thus the limitations of cross-sectional studies still apply. The variables in this study were based on self-report, and therefore, some misclassification is likely. Asthma status was based on a report of ever having been diagnosed by a healthcare provider and would not include undiagnosed cases of asthma. This could lead to biased results and an exaggeration of the true association, as immigrants from lower income countries may have less access to health care, both in their home country and in the USA and therefore might be less likely to be diagnosed with asthma. The study response rate was relatively low, which may indicate differences between this study sample and the general population that cannot be completely overcome by the weighting applied to the

Table 3 Unadjusted and adjusted logistic regression models comparing the odds of having asthma by country of birth by GNI per capita

	<i>n</i>	OR (95% CI)	<i>P</i>
Unadjusted Model			
Country of birth by GNI* per capita			
High income (GNI per capita>\$12 275)	9628	1	–
Middle income (GNI per capita \$1006–\$12 275)		0.39 (0.31; 0.50)	<0.001
Low income (GNI per capita<\$1006)		0.22 (0.08; 0.62)	0.005
Adjusted Model			
Country of birth by GNI per capita			
High income (GNI per capita>\$12 275)	8708	1	–
Middle income (GNI per capita \$1006–\$12 275)		0.36 (0.27; 0.49)	<0.001
Low income (GNI per capita<\$1006)		0.26 (0.09; 0.77)	0.014
Sex			
Female		1	–
Male		0.69 (0.55; 0.87)	0.001
Borough			
Brooklyn		1	–
Bronx		1.41 (1.04; 1.9)	0.025
Manhattan		1.27 (0.91; 1.77)	0.163
Queens		1.3 (0.96; 1.77)	0.090
Staten Island		1.16 (0.81; 1.67)	0.415
Race			
White		1	–
Black		1.73 (1.29; 2.32)	<0.001
Hispanic		1.94 (1.43; 2.64)	<0.001
Asian/Pacific Islander		1.14 (0.69; 1.87)	0.611
Other		1.89 (0.89; 4.01)	0.099
Length of time in the USA			
10+ years		1	–
<5 years		0.94 (0.38; 2.35)	0.900
5–9 years		0.18 (0.06; 0.55)	0.003
Education			
College grad		1	–
Did not graduate HS		1.59 (1.09; 2.33)	0.017
HS graduate		0.89 (0.64; 1.22)	0.452
Some college/ technical school		1.29 (0.96; 1.72)	0.087
Age			
65+		1	–
18–24		2.26 (1.38; 3.7)	0.001
24–44		1.51 (1.08; 2.09)	0.015
45–64		1.41 (1.06; 1.88)	0.019
Income (%FPL†)			
<100% FPL		1	–
100–200% FPL		1.02 (0.75; 1.39)	0.912
200–400% FPL		0.93 (0.67; 1.3)	0.689
400–600% FPL		0.82 (0.57; 1.18)	0.281
>600% FPL		0.89 (0.63; 1.24)	0.475

Table 3 (Continued)

	<i>n</i>	OR (95% CI)	<i>P</i>
Smoking status			
Never		1	–
Current		1.07 (0.82; 1.41)	0.622
Former		0.96 (0.74; 1.24)	0.757
Exposure to second-hand smoke			
No		1	–
Yes		1.125 (0.81; 1.55)	0.481
Bad air warning signs			
Did not see		1	–
Did see		1.27 (1.01; 1.596)	0.040
Disrupted by traffic noise at home			
No		1	–
Yes		1.02 (0.8; 1.32)	0.856
High blood pressure			
No		1	–
Yes		1.58 (1.23; 2.03)	0.001
Exercise regularly			
No		1	–
Yes		1.07 (0.85; 1.346)	0.557

*GNI, Gross National Income.

†FPL, Federal Poverty Level.

analyses. Participation rates may differ by immigration status and country of birth, as some immigrants living in the USA without legal status may be hesitant to participate in research studies. The weighted proportion of college graduates is high (41.9%), suggesting that the immigrants living in New York may disproportionately include the educated, urban elite of their home countries, which might dilute the association between GNI and asthma if immigrants from countries of any level of development come from the urban elite. We adjusted for a number of asthma risk factors cited in the literature (such as smoking, exposure to, for example, second-hand smoke and air pollution from traffic), but we were unable to adjust for other potential confounders such as history of living on farms, family size, and birth order, factors shown in previous literature to be associated with decreased allergy risk (5). Lastly, we can conclude that our findings of an association between GNI per capita of country of birth and asthma lend additional support to the hygiene hypothesis only under the assumption that GNI per capita was a good representation of factors associated with exposure to infections.

Our finding that there is a difference in asthma prevalence by the level of development of country of birth is consistent with the hypothesis that differences in exposure to infections may play a role in the development of asthma. Given the rising prevalence of asthma in NYC, understanding the causal mechanism may guide the development of future prevention and treatment programs for asthma.

Conflicts of interest

The authors declare no conflicts of interest.

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