Association of immigrant generational status with asthma

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Abstract

Objective We sought to examine whether asthma risk is lower in second-generation immigrants (i.e., Canadian-born children with at least one foreign-born parent) and first-generation immigrants (i.e., foreign-born children) compared with non-immigrants (i.e., Canadian-born children to Canadian-born parents).

Methods Data were obtained from the Canadian National Longitudinal Survey of Children and Youth from 1994 to 2008, which measured child health and developmental factors from birth to early adulthood. The sample included 15,799 participants aged 2–26 years. Asthma was defined as diagnosis by a health professional as having asthma, having wheezing or whistling in the chest, or use of medication for asthma.

Results Prevalence of asthma (defined as a combination of any three factors) was lower in first-generation (32%) and second-generation (34%) immigrants compared with non-immigrants (46%). After controlling for covariates, first- and second-generation immigrants had 0.21 (AOR = 0.21; 95% CI = 0.07–0.67) and 0.19 (AOR = 0.19; 95% CI = 0.09–0.39) lower odds of reporting asthma compared with non-immigrants, respectively. For every year the parent(s) of second-generation immigrants resided in Canada, the odds for asthma increased by 5% (AOR = 1.05; 95% CI = 1.02–1.06).

Conclusion Immigrant children and youth in Canada, regardless of whether they are first- or second-generation, have lower odds for asthma compared with non-immigrants.

Résumé

Objectif Nous avons voulu déterminer si le risque d’asthme est plus faible chez les immigrants de deuxième génération (enfants nés au Canada ayant au moins un parent né à l’étranger) et les immigrants de première génération (enfants nés à l’étranger) que chez les non-immigrants (enfants nés au Canada de parents nés au Canada).

Méthode Nos données provenaient de l’Enquête longitudinale nationale sur les enfants et les jeunes (1994 à 2008), qui mesurait la santé des enfants et les facteurs développementaux de la naissance au début de l’âge adulte. L’échantillon comptait 15 799 participants âgés de 2 à 26 ans. La définition de l’asthme comprenait un diagnostic d’asthme par un professionnel de la santé, une respiration bruyante ou sifflante, ou l’utilisation de médicaments contre l’asthme.

Résultats La prévalence de l’asthme (définie comme une combinaison de ces trois facteurs) était plus faible chez les immigrants de première génération (32 %) et de deuxième génération (34 %) que chez les non-immigrants (46 %). Compte tenu des covariables, la probabilité de déclarer de l’asthme était plus faible de 0,21 (rapport de cotes ajusté [RCa] = 0,21; IC de 95% = 0,07–0,67) chez les immigrants de première génération et de 0,19 (RCa = 0,19; IC de 95% = 0,09–0,39) chez les immigrants de deuxième génération que chez les non-immigrants. Chez les immigrants de deuxième génération, pour chaque année de résidence des parents au Canada, la probabilité d’asthme augmentait de 5 % (RCa = 1,05; IC de 95% = 1,02–1,06).

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Conclusion Les enfants et les jeunes immigrants au Canada, qu'ils soient de première ou de deuxième génération, présentent une probabilité d'asthme plus faible que les non-immigrants.

Keywords Asthma · Wheezing · Allergies · Immigrants · First-generation immigrants · Second-generation immigrants

Mots-clés Asthme · Respiration sifflante · Allergie · Immigrants · Immigrants de première génération · Immigrants de deuxième génération

Introduction

The highest prevalence of asthma symptoms is found in developed countries (e.g., United States, United Kingdom, Australia, and Canada) and lowest in more developing countries (e.g., China, India, and Ethiopia) (Beasley et al. 2003). In Canada, 15.2% of children and youth (aged 1–19 years) have asthma (Betancourt et al. 2014). Though the specific aetiology of asthma is unknown, many studies have shown that risk factors for asthma are multifaceted, involving the individuals' genetics, behaviours, and environment (Subbarao et al. 2009).

Among immigrants, the risk for asthma in the host country has been shown to vary based on their country of origin, age of immigration, duration of stay in the host country, and their predisposition to allergies (Cabieses et al. 2014). Migrant studies, mainly from the US and Europe, show that children born in a country with low asthma prevalence continue to have lower risk for asthma even after moving to the higher-prevalence country compared with their native-born peers (Cabieses et al. 2014). A systematic review by Cabieses et al. showed that immigrants are 40% less likely to report asthma compared with their host population (Cabieses et al. 2014). Canadian literature on this topic is limited and has been conducted in smaller jurisdictions and immigrants from a specific country of origin or ethnicity (Wang et al. 2008; Stanojevic et al. 2014; Benchimol et al. 2015). Asthma symptoms among Chinese adolescents were highest for those born in Canada, intermediate for those children who were born in China and later immigrated to Canada, and lowest for those children living in China (Wang et al. 2008). These findings suggest that environmental exposures in Canada and other countries may increase the risk of developing asthma in immigrant populations.

Migration involves changes in exposure to pollutants, allergens, socio-economic status (SES), diet, and accessibility to medical services. Studies of immigrant children present a unique opportunity to differentiate between genetic and environmental causes of asthma because, relative to the native population, immigrants undergo environmental and lifestyle changes in a short time frame (Kuehni 2011). Increased knowledge regarding modifying factors that contribute to the development of asthma in immigrants may help to reduce the risk of asthma in both the native and immigrant populations.

This study aims to utilize a population-level survey of Canadian children and youth to examine the association between asthma and first-generation immigrants (foreign-born children), second-generation immigrants (Canadian-born children with foreign-born parents), and non-immigrant children. To the best of our knowledge, no other study in Canada has examined associations between immigration background and asthma in a nationally representative sample of Canadian children and youth. The moderating effects of duration of stay in Canada, region of origin, and allergies on the association between immigration and asthma were also examined.

Methods

Sample

Data for this study were obtained from the National Longitudinal Survey of Children and Youth (NLSCY), a longitudinal survey conducted by Statistics Canada. NLSCY began in 1994 with a cohort of children aged 0 to 11 years old. Participants were followed at 2-year intervals up to eight survey cycles until 2008/2009. At each cycle, a new cohort of children between the ages of 0 and 8 were brought in and were subsequently followed up to obtain better estimates on early childhood development (Supplementary Figure 1). The survey collected information on child's social, emotional, and behavioural developments from birth to early adulthood. The majority of information was collected from parents on behalf of their children through in-person and telephone interviews. After the children turned 10 years of age, some information was directly collected from the child through self-report questionnaires or interviews. Further details regarding the NLSCY have been published elsewhere (Statistics Canada 2010).

In total, 66,826 participants completed at least one survey cycle. This study restricted the sample to participants who were introduced in an earlier cycle and participated in the final cycle in 2008/2009 ($n = 20,329$). This was carried out to utilize the non-funnel longitudinal weights provided by Statistics Canada. The survey weights account for the probability of a child being selected by the NLSCY sample with adjustment for non-response and non-coverage of population by age, sex, and province. Only one child per household was chosen to avoid clustering of participants under families. Thus, of the

1824 households with two participants, the participant with the most number of observations was chosen from each household. This study further restricted the sample to participants who can be classified as first-generation immigrant, second-generation immigrant, or non-immigrant. Canadian-born children with one Canadian-born parent and unknown birthplace for the second parent were excluded from the study ($n = 2706$) to avoid misclassification by immigrant status. Proposal for this study was approved by the Social Sciences and Humanities Research Council and Statistics Canada.

Measures

Asthma

A dichotomous scale was used to classify the presence of asthma in each participant at every survey cycle. Due to the changes in asthma-related questions between NLSCY survey cycles, the definition of asthma was constructed to reflect any differences in asthma questions between cycles. Participants, aged 0–15 years, were classified as having asthma using a three-item measure: diagnosis by a health professional as having asthma in their lifetime, wheezing or whistling in the chest at any time in the past 12 months, or took asthma medication (i.e., Ventolin, inhalers, or puffers) on a regular basis in the past 12 months. For participants aged 16 years and older, the number of asthma-related survey questions varied over NLSCY cycles, affecting the definition of asthma. At cycles 4 and 5, they were classified as having asthma using the same three-item measure as those aged 0–15 years. In cycles 6, 7, and 8, only the health professional diagnosis of asthma in their lifetime was used to classify them as having asthma.

Asthma-related questions were asked for all participants at their initial interview, but certain age groups were skipped out of the questions during some follow-up cycles to reduce survey burden. For those age groups, data were imputed using the last observation carried forward (LOCF) (Engels and Diehr 2003) procedure to reduce missing data. The imputation procedure was believed to be suitable because the majority of participants with asthma initially exhibit symptoms at an earlier age (Stern et al. 2008). Once the participant was identified as having asthma, they were classified as asthmatic for all subsequent cycles.

Asthma diagnosis

A dichotomous variable was used to classify whether or not a participant had ever been diagnosed by a health professional as having asthma. This variable was used as another outcome variable in this study to compare findings with those of the aforementioned asthma variable. The LOCF method was used to impute values for those who were skipped out of the questions.

Immigrant generational status

This is a three-level variable for immigrant generational status: (1) first-generation immigrants were classified as foreign-born participants; (2) second-generation immigrants were classified as Canadian-born participants with at least one foreign-born biological parent; and (3) non-immigrants were classified as Canadian-born participants to Canadian-born biological parents.

Allergies

Participants with allergies were either those diagnosed by a health professional or those reported as having long-term allergies. Survey questions regarding allergies changed periodically. In earlier cycles (Beasley et al. 2003; Betancourt et al. 2014; Subbarao et al. 2009), only one response category was offered (“allergies”). Afterward, three response categories were offered on allergies: food or digestive allergies; respiratory allergies (e.g., hay fever); and any other allergies. An overall allergy status was assigned to participants when food allergies, respiratory allergies, or any other allergies were reported. The LOCF procedure was used to impute values for participants who were skipped out of the questions in follow-up interviews (Burke et al. 2003).

Parent(s) region of birth

Biological parent’s region of birth was categorized as 1 = Canada; 2 = US; 3 = Europe (i.e., UK, France, Germany, and Netherlands); 4 = Asia (i.e., China, India, and Philippines); and 5 = other (i.e., Jamaica and Guyana). In cases where the mother and father were born in different regions, the region of birth with the assigned maximum value was chosen to reflect a region that is different in social and physical environments from Canada.

Parent’s time in Canada

For immigrant participants, parent’s time in Canada was assigned as the minimum number of years after immigration to Canada by the parent(s). For non-immigrants, minimum age of the parents was defined as their time in Canada. This was calculated to vary as the participants proceeded through the survey.

Parental history of asthma

Biological parent(s)’ reported history of asthma as one of their “long-term conditions” was used to assess the participant’s genetic predisposition to asthma. Positive family history has been shown to increase the risk of asthma in children in many studies (Burke et al. 2003).

Parental smoking

Parental smoking was included as proxy measure for exposure to secondhand smoking in participants. Parental smoking has been identified to increase the risk of asthma and other respiratory symptoms in children (Cook and Strachan 1999). Smoking was defined as daily or occasional smoking and it was assessed from the question “At the present time do you smoke cigarettes daily, occasionally or not at all?”

Other measures included child’s age at each cycle and maternal age at delivery. Younger maternal age at delivery has been reported to be a risk factor for asthma in participants even after controlling for the effects of maternal smoking, SES, and household size (Schwartz et al. 1990; Laerum et al. 2007).

Analysis

The estimates were weighted using the non-funnel longitudinal weights at cycle 8 to ensure that the estimates are unbiased with respect to the survey design. Logistic regression was used to examine overall associations between asthma and the predictors using non-funnel longitudinal weights, and variation estimations were performed using the 1000 bootstrap weights per child. Generalized estimation equation (GEE) regression models were used to account for repeated measures from participants throughout the survey. According to the recommendations by Statistics Canada, the non-funnel longitudinal weights were normalized to reflect the actual sample size of the study by dividing each participant’s survey weight by the average survey weight for all participants in the sample [16]. Quasi-likelihood information criterion (QIC), the goodness of fit criterion for GEE, was used to assess the best-fit model. Analyses were conducted using SAS (SAS Institute Inc. 2014).

Results

The final sample included 15,799 participants aged 2–26 years. Of those, 46% ($n = 7207$) joined the survey at cycle 1 and the remaining 54% joined the survey in three separate cohorts: cycle 5 (15%); cycle 6 (18%); and cycle 7 (22%). The sample comprised 1% of first-generation immigrants, 17% of second-generation immigrants, and 82% of non-immigrants. The distribution of immigrants in the final sample was similar to that of the total NLSCY sample (1%, 15%, and 66%, respectively).

Presence of any allergies (odds ratio (OR) = 2.83; 95% CI = 2.56–3.12) and parental history of asthma (OR = 2.36; 95% CI = 2.0–2.78) showed the highest odds for asthma compared with other characteristics (Table 1). Parental smoking increased the participant’s odds for asthma by

1.39 (95% CI = 1.24–1.55) (Table 1). First-generation immigrants and second-generation immigrants reported a lower prevalence of asthma (32% and 34%, respectively) compared with the non-immigrant participants (46%) throughout the survey (Table 2). In the logistic regression analysis, first-generation immigrants and second-generation immigrants had 0.57 (95% CI = 0.34–0.95) and 0.61 (95% CI = 0.53–0.70) (respectively) lower odds of reporting overall asthma compared with non-immigrant participants. In the GEE analysis using repeatedly measured asthma status from all cycles, second-generation immigrants reported 0.65 lower odds (95% CI = 0.56–0.75) for asthma compared with non-immigrants, but the findings for first-generation immigrants were not statistically significant (Table 1). Second-generation immigrants had 0.80 lower odds of reporting asthma diagnosis by a health professional (95% CI = 0.66–0.96) and 0.58 lower odds of reporting wheezing (95% CI = 0.51–0.68) compared with non-immigrants (Table 2). Use of asthma medication was significantly lower in second-generation immigrants compared with non-immigrants (OR = 0.79; 95% CI = 0.64–0.97).

First-generation immigrants (adjusted odds ratio (AOR) = 0.12; 95% CI = 0.07–0.23) and second-generation immigrants (AOR = 0.12; 95% CI = 0.04–0.34) had significantly lower odds for asthma compared with non-immigrants in the multivariable analysis controlling for the effects of participant’s age, parent’s time in Canada, and interaction between generation and parent’s time in Canada (Table 3, model 1). When the model was adjusted for additional covariates (allergies, parental history of asthma, parental smoking, participant’s age, and maternal age at delivery), excluding the interaction between generation and parent’s time in Canada, the odds of reporting asthma increased to 0.55 (95% CI = 0.24–1.28) in first-generation immigrants and 0.61 in second-generation immigrants (95% CI = 0.45–0.82) (model 2). The final model, which included the interaction between generation and parent’s time in Canada, showed first-generation (AOR = 0.21; 95% CI = 0.07–0.67) and second-generation immigrants (AOR = 0.19; 95% CI = 0.09–0.39) have significantly lower odds for asthma compared with non-immigrants. The odds of a second-generation immigrant reporting asthma increased by 1.05 (95% CI, 1.02–1.06) for every year the participant’s parent(s) lived in Canada. Comparison of QIC values for all multivariable models revealed the full model for immigrant status with the interaction term as the best-fit model (model 3).

Similar to the findings for asthma, analysis of health professional diagnosis showed that presence of allergies and parental history of asthma are the biggest risk factors for asthma (Table 1). Parental smoking and age at time of interview also showed significantly higher odds for asthma diagnosis. Parental smoking increased the participant’s odds for asthma diagnosis by 55%. Unlike the findings for asthma, participants

Table 1 Bivariate repeated measure models examining the association of asthma with select characteristics

Characteristics	Unweighted <i>n</i> ¹	Asthma ²		Asthma diagnosis	
		OR	95% CI	OR	95% CI
Immigrant status					
First-generation immigrants	190	0.79	(0.46–1.34)	1.08	(0.57–2.06)
Second-generation immigrants	2645	0.65**	(0.56–0.75)	0.9	(0.74–1.11)
Non-immigrants	12,965	Ref		Ref	
Parent(s) region of birth					
US	325	0.94	(0.63–1.38)	1.38	(0.52–1.64)
Europe	790	0.80	(0.63–1.01)	1.01	(0.9–1.62)
Asia	510	0.61*	(0.43–0.86)	0.86	(0.48–1.3)
Other	1160	0.54**	(0.42–0.68)	0.68	(0.54–1.03)
Canada	12,995	Ref		Ref	
Allergies (combined)					
Yes	4950	2.83**	(2.56–3.12)	3.12**	(3.09–3.88)
No	10,845	ref		Ref	
Food allergies					
Yes	1540	1.93**	(1.6–2.32)	2.32**	(1.93–2.88)
No	14,080	Ref		Ref	
Respiratory allergies					
Yes	1830	3.33**	(2.81–3.94)	3.94**	(3.64–5.12)
No	13,790	Ref		Ref	
Any other allergies					
Yes	2595	2.30**	(2.0–2.65)	2.65**	(2.01–2.7)
No	13,025	Ref		Ref	
Parental asthma					
Yes	2280	2.36**	(2.0–2.78)	2.78**	(2.44–3.55)
No	13,490	Ref		Ref	
Parental smoking					
Yes	6950	1.39**	(1.24–1.55)	1.55**	(1.24–1.55)
No	8845	Ref		Ref	
Parent's time in Canada	15,550	1.00	(1.0–1.01)	1.01	(0.99–1.01)
Age at the time of interview	15,800	1.02**	(1.02–1.03)	1.03**	(1.06–1.08)
Maternal age at delivery	15,710	1.00	(0.99–1.01)	1.01	(0.98–1.01)

¹ Numbers have been rounded to the nearest 5. ² Asthma is defined as diagnosis by a health professional as having asthma, having wheezing or whistling in the chest, or taking Ventolin, inhalers, or puffers for asthma in their lifetime. **p* value < 0.05, ***p* value < 0.001

with parents born in Asia and other countries did not show any significant difference for asthma diagnosis (Table 1).

The rate of asthma diagnosis was lower in second-generation immigrants compared with non-immigrant participants (19% vs. 22%; 95% CI 0.66–0.96); however, there were no significant differences in rates between first-generation immigrants and non-immigrants (Table 2). Multivariable analysis (Table 4) showed first-generation immigrants (AOR = 0.28; 95% CI = 0.08–0.93) and second-generation immigrants (AOR = 0.27; 95% CI = 0.13–0.55) had significantly lower odds for health professional diagnosis of asthma compared with non-immigrants (model 1). The odds of a second-

generation immigrant having a diagnosis for asthma increased 4% for every year the participant's parent(s) lived in Canada (model 1). When the model was adjusted for additional covariates, the association between immigrant generation status and asthma diagnosis was no longer statistically significant (model 3).

Discussion

Our analysis of over 15,000 participants found that immigrants from all regions (including other industrialized nations)

Table 2 Association between ever reporting of asthma-related symptoms by generation of immigrants using logistic regression analyses

Characteristics	First-generation immigrant (n = 190)	Second-generation immigrant (n = 2645)	Non-immigrants (n = 12,965)	Total (n = 15,799)	First-generation immigrants vs. non-immigrants		Second-generation immigrants vs. non-immigrants	
	%	%	%		OR	95% CI	OR	95% CI
Asthma ¹								
Yes	32	34	46	42	0.57	(0.34–0.95)	0.61	(0.53–0.70)
No	68	66	54	58				
Asthma diagnosis								
Yes	22	19	22	21	0.99	(0.54–1.82)	0.80	(0.66–0.96)
No	78	81	78	79				
Wheezing								
Yes	30	28	40	37	0.64	(0.38–1.09)	0.58*	(0.51–0.68)
No	70	72	60	63				
Use of asthma medication ²								
Yes	17	12	14	14	1.23	(0.62–2.43)	0.79*	(0.64–0.97)
No	83	88	86	86				
Allergies								
Yes	39	34	38	37	1.05	(0.64–1.72)	0.85	(0.74–0.97)
No	61	66	62	63				

¹ Asthma is defined as diagnosis by a health professional as having asthma, having wheezing or whistling in the chest, or taking Ventolin, inhalers, or puffers for asthma in their lifetime. ² Medications included Ventolin and inhalers or puffers for asthma

n, unweighted number of participants; %, weighted percent; *p value < 0.05

have a lower risk for asthma in Canada compared with Canadian-born participants with Canadian-born parents. First- and second-generation immigrants have lower odds for asthma compared with non-immigrants, even after adjusting for possible confounders like parent's age, history of asthma, and smoking. The risk for asthma is relatively similar between first- and second-generation immigrants compared with non-immigrant participants. Finally, parent's length of time living in Canada increases the risk of acquiring asthma in immigrant participants, but only at a very slow rate.

We found that a parent born in a foreign country is a protective factor for asthma in Canadian-born participants. This suggests that the protective effect of being a foreign-born is passed onto the next generation by parents. A study from Sweden also reported a protective effect for asthma in second-generation immigrants. In the study, Swedish-born participants with foreign-born mothers showed lower risk of being admitted to the hospital for asthma compared with participants of Swedish-born mothers (Hjern et al. 1999). Our study showed no significant difference in odds for asthma between first- and second-generation immigrants. However, review of five studies by Cabieses et al. showed first-generation immigrants have lower odds for asthma (pooled OR, 0.37; 95% CI, 0.25–0.58) compared with second-generation immigrants (Cabieses et al. 2014). Several studies that examined the risk of asthma by ethnicity, an indicator of immigrants from many generations, have also reported a protective effect for asthma in ethnic minorities in the US and UK (Akinbami et al. 2009; Netuveli et al. 2005; Whitrow and Harding 2010). Together, being an immigrant is a protective

factor for asthma, regardless of whether it was the child or the parent who immigrated to Canada.

Finally, we showed a gradual increase in the probability of asthma in participants as their parent(s) lived longer in Canada. This is the first Canadian study to examine the relationship by parent's length of stay. Other international studies that explored the association by participants' length of stay in the host country also reported a negative correlation between length of stay and asthma (Cabieses et al. 2014). This association is often explained using the hygiene hypothesis, which suggests that foreign-born immigrants have better immunity against the development of asthma in their host country due to their early childhood exposure to infections in their country of birth (Rottem et al. 2005). Our findings on the rate at which the protective effects change in immigrants varied from findings in the literature. Other studies have shown a relatively accelerated development of asthma in immigrants than what was seen in this study (Eldeirawi et al. 2009; Migliore et al. 2007). Mexican-born participants who lived in the US for more than 10 years reported a significant increase (2.3 odds) in development of asthma compared with their counterparts who lived in the US for less than 10 years (Eldeirawi et al. 2009). For every additional year immigrant children resided in Italy, there was a 12% increase in the odds for asthma (Migliore et al. 2007). The reason for discordant findings may include the differences in the use of child's vs. parent's time in Canada, sampling frame for immigrant population, and the environment in the host country.

One of the limitations of this analysis is around the broad definition of asthma used (physician diagnosis or symptoms or

Table 3 Multivariable repeated measure models examining association between generation of immigrants and asthma

Characteristics	Asthma ¹					
	Model 1		Model 2		Model 3	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Generation						
First-generation immigrants	0.12*	(0.07–0.23)	0.55	(0.24–1.28)	0.21*	(0.07–0.67)
Second-generation immigrants	0.12*	(0.04–0.34)	0.61*	(0.45–0.82)	0.19*	(0.09–0.39)
Non-immigrants	Ref		Ref		Ref	
Parent(s) region of birth						
Asia			0.64*	(0.43–0.96)	0.73	(0.48–1.10)
Other			0.61	(0.36–1.06)	0.74	(0.42–1.31)
Canada/US/Europe			Ref		Ref	
Parent's time in Canada ²	0.95*	(0.94–0.97)	0.98*	(0.97–0.99)	0.96*	(0.94–0.97)
Generation * parent's time in Canada						
First-generation * parent's time in Canada	1.07	(0.96–1.18)			1.04	(0.94–1.17)
Second-generation * parent's time in Canada	1.05*	(1.03–1.07)			1.05*	(1.02–1.06)
Non-immigrants * parent's time in Canada	Ref				Ref	
Allergies (combined)						
Yes			2.70*	(2.40–3.03)	2.65*	(2.36–2.98)
No			Ref		Ref	
Parental asthma						
Yes			2.30*	(1.86–2.84)	2.29*	(1.85–2.85)
No			Ref		Ref	
Parental smoking						
Yes			1.43*	(1.24–1.65)	1.41*	(1.22–1.63)
No			Ref		Ref	
Child's age at the time of interview	1.04*	(1.03–1.04)	1.03*	(1.02–1.03)	1.03*	(1.02–1.04)
Maternal age at delivery			1.00	(0.99–1.02)	1.00	(1.00–1.02)
Quasi-likelihood information criterion	77,589		71,161		71,062	

¹ Asthma is defined as diagnosis by a health professional as having asthma, having wheezing or whistling in the chest, or taking Ventolin, inhalers, or puffers for asthma in their lifetime. ² For immigrant participants, parent's time in Canada was assigned as the minimum number of years after immigration to Canada; for non-immigrants, minimum age of the parents was defined as their time in Canada. **p* value < 0.05

medication use) to classify participants. There is no gold standard for detecting asthmatic participants in epidemiological studies (Pekkanen and Pearce 1999). Many studies have traditionally used professional diagnosis to define asthma (Lara et al. 2006; Yu et al. 2004). The broad definition used in this study showed much higher prevalence of asthma (43%) compared with the nationally reported prevalence (15.2%) (Betancourt et al. 2014) and is likely due to inclusion of wheezing in our definition. This definition of asthma was used to capture all asthmatic participants who may or may not have been diagnosed, including recent immigrants who may not have had the opportunity to be diagnosed by a health professional. This may have resulted in some misclassification of participants who wheeze but do not have asthma. Other studies

examining the validity of asthma measures have indicated that inclusion of wheezing is an appropriate measure for studying asthma (Yu et al. 2004; Thomas 2010; Remes et al. 2002; Hederos et al. 2007; Pekkanen et al. 2005). As a single measure, wheezing was shown to have 78% sensitivity and 97% specificity with clinically diagnosed asthma (Remes et al. 2002). In order to overcome some of these limitations and for comparability with other studies, analysis by asthma diagnosis was carried out, but due to smaller number of participants in this group, many findings were not statistically significant.

Use of the LOCF method to reduce missing data and make corrections to discrepant reporting of asthma may have resulted in misclassification of participants with asthma. Assuming that report of asthma at an earlier cycle was more accurate than

Table 4 Multivariable repeated measure models examining association between generation of immigrants and asthma diagnosis by health professional

Characteristics	Asthma diagnosis					
	Model 1		Model 2		Model 3	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Generation						
First-generation immigrants	0.28*	(0.08–0.93)	0.94	(0.35–2.51)	0.66	(0.16–2.75)
Second-generation immigrants	0.27*	(0.13–0.55)	1.07	(0.74–1.56)	0.55	(0.24–1.29)
Non-immigrants	Ref		Ref		Ref	
Parent(s) region of birth						
Asia			0.70	(0.35–1.39)	0.77	(0.38–1.58)
Other			0.74	(0.46–1.18)	0.79	(0.49–1.27)
Canada/US/Europe			Ref		Ref	
Parent's time in Canada ²	0.97*	(0.95–0.98)	0.99	(0.98–1.01)	0.98*	(0.96–1.00)
Generation * parent's time in Canada						
First-generation * parent's time in Canada	1.02	(0.90–1.17)			0.98	(0.96–1.00)
Second-generation * parent's time in Canada	1.04*	(1.01–1.07)			1.02	(1.00–1.05)
Non-immigrants * parent's time in Canada	Ref				Ref	
Allergies (combined)						
Yes			2.79*	(2.46–3.18)	2.77*	(2.43–3.34)
No			Ref		Ref	
Parental asthma						
Yes			2.98*	(2.37–3.75)	2.97*	(2.36–3.76)
No			Ref		Ref	
Parental smoking						
Yes			1.28*	(1.08–1.53)	1.27*	(1.06–1.51)
No			Ref		Ref	
Child's age at the time of interview	1.06*	(1.05–1.07)	1.05*	(1.04–1.06)	1.05*	(1.04–1.06)
Maternal age at delivery			1.00	(0.98–1.01)	1.00	(0.98–1.02)
Quasi-likelihood information criterion	60,408		54,533		54,551	

¹ For immigrant participants, parent's time in Canada was assigned as the minimum number of years after immigration to Canada; for non-immigrants, minimum age of the parents was defined as their time in Canada. **p* value < 0.05

denial of asthma at a later cycle may have led to non-random misclassification of participants. Sensitivity analyses were carried out on the LOCF method by comparing models presented in this paper to models using two other approaches: (1) carried forward responses for those who were skipped out of the asthma questions, but with no changes for discrepant reporting of asthma, and (2) no adjustment to asthma outcomes. Comparison of bivariate models showed similar effects for first- and second-generation immigrants across all three approaches. For multivariable models, the protective effect for asthma and asthma diagnosis among second-generation immigrants was still significant after controlling for age, parent's length of stay in Canada, and the interaction between generation and parent's time in Canada (model 1 in Tables 3 and 4). After controlling parent's place of birth, presence of

allergies, parental history of asthma, and parental smoking (models 2 and 3 in Tables 3 and 4), the protective effect was no longer significant for both approaches, which may have been attributable to the loss of observations due to deletion of missing values across all variables. Since the bivariate and initial multivariable models showed similar associations and the effect size presented in the study is similar or lower compared with the other two sensitivity approaches, we believe there is minimal bias associated with using the LOCF method.

Another limitation of this study may be an underrepresentation of recent immigrants. The original cohort was developed to be representative of the population, but over time, the sample design did not specifically ensure an adequate sample of new immigrants. As the original cohort grew older,

the NLSCY topped up the sample with young children and these may have included some recent immigrants.

One of the major strengths of this study is that as a population-level study across Canada, this study provides more generalizable findings of Canadians. Unlike other studies, the large sample ($n > 18,000$) allowed for adjustments for many covariates—including parent's region of birth. The use of a common definition for asthma, health professional diagnosis, allows for greater comparability across studies. In addition, this study contributes to the limited number of studies that have examined the association between second-generation immigrants and asthma. The slower rate of increase in asthma development seen among immigrants in this study compared with that in the US indicates the need for consideration of social context in the relationship between asthma and generation of immigrants.

Future studies should examine this association closer through the use of objective measures for asthma. This study also emphasizes the need for prospective research on factors influencing the change in immunity among immigrant participants. Soon after migration, many immigrants experience decline in SES and acculturation challenges. Many often live in low-income neighbourhoods that may expose them to neighbourhood-level risk factors. Better knowledge of the contributing factors for the development of asthma in immigrant population will protect against environmental factors (food, culture, and physical environment) in both immigrant and non-immigrant populations.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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