SYSTEMATIC REVIEW

The Population Attributable Fraction of Asthma Among Canadian Children

Elinor Simons, MD, MSc,[1] Teresa To, MSc, PhD,[1] Sharon Dell, MD[1,2]

ABSTRACT

Objective: We calculated the population attributable fraction (PAF) of Canadian childhood asthma due to modifiable environmental exposures, in order to estimate their relative contributions to asthma development based on the current literature.

Methods: We conducted a systematic review to determine Canadian childhood asthma incidence, Canadian prevalence of exposure to airborne pollutants and indoor allergens, and international estimates of the risk of developing physician-diagnosed asthma (PDA) associated with each exposure. Combining risk estimates by meta-analysis where possible, PAF was calculated by the formula:

$$PAF = \frac{\text{Attributable risk} * \text{Exposure prevalence} * 100\%}{\text{Asthma incidence}}$$

Synthesis: Age-specific Canadian childhood asthma incidence ranged from 2.8%-6.9%. Canadian exposure prevalences were: PM_{10} 16%, $PM_{2.5}$ 7.1%, NO_2 25%, environmental tobacco smoke (ETS) 9.0%, cat 22%, dog 12%, mouse 17%, cockroach 9.8%, dust mite 30%, moisture 14% and mould 33%. Relative risk estimates of PDA were: PM_{10} 1.64, $PM_{2.5}$ 1.44, NO_2 1.29, ETS 1.40, mouse 1.23, cockroach 1.96, and spanned 1.00 for cat, dog, dust mites, moisture and mould. PAF estimates for incident asthma among preschool children were: PM_{10} 11%, $PM_{2.5}$ 1.6%, NO_2 4.0%, ETS 2.9%, mouse 6.5% and cockroach 13%.

Conclusions: This systematic review suggests contributions to childhood asthma development from exposure to particulates, NO_2, ETS, mouse and cockroach. The associations appeared to be more complex for cat, dog and dust mite allergens and more variable for mould and moisture. Additional prospective, population-based studies of childhood asthma development with objectively-measured exposures are needed to further quantify these associations.

Key words: Asthma; children; population attributable fraction; environmental exposure

La traduction du résumé se trouve à la fin de l'article.

Can J Public Health 2011;102(1):35-41.

Asthma is a leading cause of chronic illness among Canadian children. Quantifying the relative contributions of modifiable exposures to the development of Canadian childhood asthma may identify the most effective targets for individual and societal intervention and suggest future research targets.

Our objective was to determine the population attributable fraction (PAF) of childhood asthma in Canada due to modifiable environmental exposures, including particulates, nitrogen dioxide (NO_2), environmental tobacco smoke (ETS), cat, dog, mouse, cockroach, dust mites, moisture and mould, in order to estimate their relative contributions to childhood asthma development. The PAF, or proportion of childhood asthma in Canada that may be attributed to these exposures, was calculated using Canadian childhood asthma incidence, Canadian pollutant exposure prevalence, and international estimates of the risk of asthma development associated with exposure.

METHODS

Inclusion and exclusion criteria

Canadian Childhood Asthma Incidence

Estimates of asthma incidence among Canadian children were obtained from representative national surveys – the National Longitudinal Survey of Children and Youth (NLSCY)[1] and the National Population Health Survey (NPHS)[2] – and population or administrative databases.[3,4]

Canadian Exposure Prevalence

Canadian environmental pollutant and allergen exposure prevalences were estimated from websites of government agencies and published studies. Cut points for airborne pollutant levels contributing to asthma development have not been defined; therefore, we used the 2005 World Health Organization Air Quality Standards,[5] which have been associated with cardio-respiratory problems [PM_{10} 50 $\mu g/m^3$, $PM_{2.5}$ 25 $\mu g/m^3$, NO_2 21 parts per billion (ppb), O_3 47 ppb, and SO_2 7.1 ppb]. The Canada-Wide Air Quality Standard[6] was used for CO (11 parts per million) in the absence of a WHO Standard. The prevalence of environmental tobacco smoke (ETS) exposure was obtained from the Canadian Tobacco Use Monitoring Survey.[7] Pet, pest, moisture and mould exposures were self-reported, observed, or determined using allergen levels associated with asthma symptom development (cat >8µg/g, dog >10µg/g, mouse >1.6µg/g, cockroach >8U/g and dust mites >10µg/g).

Author Affiliations

The Hospital for Sick Children, Toronto, ON
1. Child Health Evaluative Sciences
2. Respiratory Medicine

Correspondence: Dr. Elinor Simons, The Hospital for Sick Children Research Institute, Child Health Evaluative Sciences, 555 University Avenue, Toronto, ON M5G 1X8, Tel: 416-813-7654, ext. 28536, Fax: 416-813-5979, E-mail: elinor.simons@sickkids.ca

Acknowledgements: We gratefully acknowledge funding from Health Canada, AllerGen and the Hospital for Sick Children.

Conflict of Interest: None to declare.

International Estimates of Risk

Studies associating incident childhood asthma and outdoor airborne pollutants were included if the pollutant levels were determined by monitoring device and geo-coded to home or school address, and excluded if they used traffic counts, proximity to roadways, gas stoves, or attached garages as surrogate exposure measures. ETS was reported as maternal smoking or number of daily cigarettes. Pet, pest and dust mite exposures were determined by allergen levels. Moisture and mould exposures were self-reported or observed. The studies used validated questionnaires to determine reported exposures.

Study outcomes included incident physician-diagnosed asthma (PDA) and persistent wheezing determined by a validated questionnaire or by International Classification of Disease (ICD-9) code. Studies of worsening asthma control, asthma exacerbations or asthma medication use were excluded. Studies of prevalent asthma were included in the review but not in the PAF calculation.

Criteria for selection of studies from the literature

OVID MEDLINE searches of peer-reviewed original and review articles were conducted. For asthma incidence, the search terms were: Canada (including provinces, territories and abbreviations) AND asthma (including exercise-induced asthma, bronchial hyper-reactivity, and an epidemiology subheading) AND child (age 0-18 years). For exposure prevalence, the search terms were: Canada (including provinces, territories and abbreviations) AND exploded terms for each exposure. For risk estimates, the search terms were: asthma (including exercise-induced asthma, bronchial hyper-reactivity, and an epidemiology subheading) AND child (age 0-18 years) AND exploded terms for each exposure. Searches were refined with the aid of library scientists with expertise in systematic reviews and were limited to English or French articles. The literature searches generated 6,659 citations, many of which were not directly related to the question of interest; 115 studies were reviewed in detail and 84 studies were included in the review. Dissertations and unpublished studies were evaluated in ProQuest using similar strategies.

Approach to the estimation of population attributable fraction

PAF was determined by two algebraically-equivalent formulae[8,9] (Appendix I).

Formula 1a

$$PAF = \frac{\text{Attributable risk (AR)} * \text{Risk factor exposure prevalence} * 100\%}{\text{Total asthma incidence}}$$

Formula 1b

$$PAF = \frac{(OR - 1)}{OR} * \text{Proportion exposed of those with incident asthma} * 100\%$$

AR was calculated from the odds ratio (OR), an estimate of relative risk (RR) among studies with stable exposure distribution.[10]

Formula 2

AR = rate of disease in unexposed children * (OR –1)

To evaluate for bias in the publication or selection of studies estimating the risk of asthma development due to modifiable exposures, funnel plots of OR versus the study sample size were generated for each exposure. For exposures having more than one study with similar populations, outcomes, exposures, designs and methods, the central measures of AR for PAF calculation were determined by random effects meta-analyses, allowing weighting of each study's contribution to the overall effect.[11]

SYNTHESIS

Canadian childhood asthma incidence

From cycles I and II of the NLSCY and NPHS,[1,2] Canadian childhood asthma incidence ranged from 2.8%-6.9% and agreed with British Columbia[3] and Manitoba[4] population-based data and Ontario administrative data (personal communication, Dr. Teresa To)(Table 1).

Pollutant and allergen prevalence levels

Airborne pollutant exposure varied widely depending on the time of day[12] and season[13] and whether overall averages[12-19] or maximum levels[6,20] were reported. Among the studies evaluated, the median outdoor pollutant prevalences, or percentages of the population with exposure greater than the threshold level, were: PM_{10} 16%, $PM_{2.5}$ 7.1%, NO_2 25%, O_3 22%, SO_2 0.1% and CO 0.1%. Indoor $PM_{2.5}$ and NO_2 exposure prevalences were determined using original data[21,22] (indoor $PM_{2.5}$ 1.7% and indoor NO_2 3.3%) and summary measures.[23-25] The 2006 ETS exposure prevalence for 0-12 year-old children (9%) and cigarette use prevalence among 15-19 year-olds (15%) improved from 25% in 2000.[7] Allergen prevalences in Canadian homes were: cat 22%, dog 12%, mouse 17%, cockroach 9.8%, dust mites 30%, moisture or dampness 14%, and mould 33%.[21-23,26]

Studies presenting an estimate of risk

Odds ratios (ORs) describing associations between environmental exposure and incident PDA or wheezing (Table 2) were: PM_{10} 1.64,[27] $PM_{2.5}$ 1.32-1.56,[28-30] NO_2 1.04-1.60,[27-30] SO_2 <1.00,[27] ETS <1.00-1.6,[31-36] mouse 1.23,[37] cockroach 1.96,[37] moisture <1.00-1.16[38,39] and mould <1.00-2.44.[36,38] For exposure to cat,[37,39-45] dog,[37,39-42] and dust mite allergens,[37,41,46-48] the ORs spanned 1.00 and suggested non-linear positive associations in many studies.

For AR determination (Table 3), random effects meta-analyses were conducted for $PM_{2.5}$ (2 cohorts) and NO_2 (3 cohorts). For ETS, moisture and mould, the study methods were very different and meta-analyses were deemed inappropriate. For ETS, the OR estimates were fairly consistent and the median was used for AR calculation. For PM_{10}, mouse and cockroach, ORs were determined from a single prospective study. For cat, dog and dust mite allergens, PAF calculation could not adequately summarize the non-linear associations.

Estimate of the population attributable fraction

Population attributable fractions (PAFs) of incident asthma were generated using longitudinal NLSCY data by age group (Table 4). Most studies of risk estimates were conducted in preschool children and the PAF estimates for the 0-4 age group were: PM_{10} 11%, outdoor $PM_{2.5}$ 1.6%, indoor $PM_{2.5}$ 0.38%, outdoor NO_2 4.0%, indoor NO_2 0.53 and ETS 2.9%. PAFs calculated using provincial asthma incidence data from Ontario, British Columbia and Manitoba were similar for younger children, but elevated for older age groups (Table 5), likely due to the lower asthma incidence among older

Table 1. Asthma Incidence From Canadian Studies in the Literature

Study	Data Source	Years	N	Age (years)	Asthma Incidence % (95% confidence interval, where presented)
Midodzi 2007[1]	NLSCY cycles 1 & 2	1994-95 1996-97	13,524	0-1 2-5 6-11	6.9* 5.3* 4.9*
Chen 2002[2]	NPHS cycles 1 & 2	1994-95 1996-97	12,636	12-24	Male 2.8 (1.7-3.9)* Female 5.3 (3.6-7.0)*
Marra 2009[3]	British Columbia All live births	1997-2003	251,817	2-3 3-5 5-9	2.72 (2.71-2.72) ** 2.41 (2.40-2.41) ** 1.74 (1.74-1.75) **
Dik 2004[4]	Manitoba Population Health Research Repository	1980-90	170,960	1 2 5-6	2.6*** 2.9*** 2.0***
To (personal communication)	Ontario Administrative Database	2005	777,778	0-4 5-9 11-14 15-19	3.5** 1.0** 0.5** 0.3**

NLSCY National Longitudinal Survey of Children and Youth; NPHS National Population Health Survey
* 2-year cumulative incidence (%)
** Incident cases per 100 person-years
*** Yearly cumulative incidence (%)

Table 2. Studies Describing the Estimated Risk of Incident Asthma or Wheezing Development

Study	Exposure	Odds Ratio	95% Confidence Interval	Exposure Measure	Outcome
Nordling 2008[27]	PM_{10}	1.64	0.90-3.00	Dispersion model	Persistent wheezing
Brauer 2007[29]	$PM_{2.5}$	1.32	0.96-1.83	Fixed-site monitors	PDA
Morgenstern 2008[28]	$PM_{2.5}$	1.56	1.03-2.37	Fixed-site monitors	PDA or bronchitis
Brauer 2007[29]	NO_2	1.29	0.99-1.69	Fixed-site monitors	PDA
Morgenstern 2008[28]	NO_2	1.04	0.67-1.39	Fixed-site monitors	PDA or bronchitis
Nordling 2008[27]	NO_2	1.60	1.09-2.36	Dispersion model	Persistent wheezing
Nordling 2008[27]	SO_2	0.69	0.37-1.29	Dispersion model	Persistent wheezing
Martel 2009[36]	ETS	1.22	1.00-1.49	Maternal smoking	ICD-9 + medication
Balemans 2006[31]	ETS	1.6	1.0-2.6	Maternal smoking	PDA age 21
Jaakkola 2004[32]	ETS	1.31	1.09-1.58	Prenatal >10 cig/day	Registry report age 7
Ronmark 2002[33]	ETS	0.66 1.26	0.34-1.28 0.92-1.73	Maternal smoking	PDA age 7-8 years Wheezing age 7-8
Strachan 1998[34]	ETS	1.31	1.22-1.41	Maternal smoking	Wheezing age 6
Lewis 1995[35]	ETS	1.44	1.27-1.63	Prenatal >15 cig/day	Wheezing age 5
Phipatanakul 2005[37]	Mouse	1.23	0.79-1.93	Detectable kitchen allergen	Wheezing age 1
Phipatanakul 2005[37]	Cockroach	1.96	1.17-3.31	Allergen ≥0.05 U/g	Wheezing age 1
Jaakkola 2005[38]	Surface damp Water damage	0.92 1.01	0.54-1.54 0.45-2.26	Home	PDA
Perzanowski 2002[39]	Dampness	1.16	0.69-1.94	Home	PDA
Martel 2009[36]	Bedroom mould	0.99	0.71-1.37	Prenatal	ICD-9 + medication
Jaakkola 2005[38]	Mould odour Visible mould	2.44 0.65	1.07-5.60 0.24-1.72	Home	PDA

PM_{10} Particulate matter with aerodynamic diameter less than 10 μm
$PM_{2.5}$ Particulate matter with aerodynamic diameter less than 2.5 μm
ETS Environmental tobacco smoke
PDA Physician-diagnosed asthma
ICD-9 International Classification of Disease code

children. For mouse and cockroach, wheezing prevalences among a cohort of highly exposed children in the first year of life were 34.5% and 26.8% and PAFs were 6.5% and 13% (Formula 1b), respectively.[37]

A few studies suggested different exposure contributions depending on the asthma or wheezing phenotype. A birth cohort followed until age 8 years[30] showed greater effects due to early outdoor $PM_{2.5}$ and NO_2 exposure for persistent wheezing (present <3 years and at 6 years, PAFs 1.1% and 3.1%, respectively) than for late-onset wheezing (not present <3 years but present at 6 years, PAFs 0.52% and 1.3%, respectively). Another birth cohort demonstrated a greater contribution of ETS exposure to persistent wheezing (PAF 12%) than late-onset wheezing (PAF 6.4%).[49] However, for mouse allergen exposure, PAFs of children followed until age 7 years[37,50] were greater for transient (6.6%) and late-onset (8.7%) wheezing than for persistent wheezing (0%).

DISCUSSION

Summary of results

This review suggests associations between childhood asthma and exposure to particulates, NO_2, ETS, mouse and cockroach. Most studies of risk estimates were conducted in preschool children and the PAF estimates for this age group were: PM_{10} 11%, outdoor $PM_{2.5}$ 1.6%, indoor $PM_{2.5}$ 0.38%, outdoor NO_2 4.0%, indoor NO_2 0.53, ETS 2.9%, mouse 6.5% and cockroach 13%. The contribution to childhood asthma development was most convincing for ETS because few OR confidence intervals crossed 1.00. However, one

study of incident asthma in older children[33] had an OR <1.00, suggesting greater effects in young children. The PAF for ETS (2.9%) has changed substantially since 2000 (8.0%) as the exposure prevalence has decreased. Data from a few studies also suggested that exposure contribution to asthma development depended on the asthma or wheezing phenotype.

Study validity

Among studies estimating the risk of asthma due to exposure, standardized methods were used to conduct geo-coding of outdoor airborne particulate and pollutant gas levels to home addresses. The methods used to determine exposure to the other modifiable environmental factors were also standardized and reproducible, including internationally-validated questionnaire items for parent-reported ETS, pet, vermin, mould and moisture exposure and standardized protocols for allergen level determination. Internationally-validated questionnaires were also used to determine parental report of asthma and physician-diagnosed asthma. Therefore, these studies should be relevant to Canadian children, although many were conducted in other countries.

Effects of study variation

The studies of incident asthma varied in the method of reporting incidence and studies of exposure prevalence varied extensively with respect to measurement time, day and season, reducing the estimate precision. Among studies estimating the risk of asthma development, the airborne pollutant cut points for OR calculation varied by study and ETS studies did not have consistent exposure (e.g., prenatal versus overall maternal smoking) and outcome definitions (e.g., ICD-9 codes versus report of asthma diagnosis). For mouse and cockroach allergens, few studies evaluated both population-based prevalence and risk, and the exposure prevalences were higher in studies that estimated risk than in studies estimating the prevalence of exposure among Canadian children. The variability among OR estimates for pet allergens may have been accounted for by different approaches to defining exposure (e.g., by study tertile versus allergen level). The variation among moisture and mould studies reflected the difference between report and observation and the difficulty of defining exposure severity.

As discussed below, the effects of study variability for particulate and pollutant levels may have caused over- or underestimation of PAF. For ETS, the consistency of the associations suggests that the effects of variability are minimal. However, confidence in the PAF would be improved with more similar definitions of ETS exposure and outcome. For mouse and cockroach, risk estimates in populations of varying exposure prevalence are needed. The breadth of study variability precluded PAF calculation for pets, dust mites, moisture and mould.

Funnel plot symmetry suggested the absence of publication and selection bias among studies estimating the risk of asthma development due to the exposures reviewed. Therefore, the implications of unpublished or unretrieved literature should be minimal. However, other systematic reviews calculating the PAF of childhood incident asthma were not found, so our results cannot be directly compared with previous studies.

Table 3. Calculation of Attributable Risk of Incident Asthma Related to Pollutants

Study	Pollutant	Individual Odds Ratio	Asthma Incidence in Unexposed	Attributable Risk
Nordling 2008[27]	PM_{10}	1.64	0.055*	0.035
Brauer 2007[29]	$PM_{2.5}$	1.32	0.010*	0.0033
Morgenstern 2008[28]	$PM_{2.5}$	1.56	0.027	0.015
Brauer 2007[29]	NO_2	1.29	0.010*	0.0030
Morgenstern 2008[28]	NO_2	1.04	0.027	0.0011
Nordling 2008[27]	NO_2	1.60	0.055*	0.033
Nordling 2008[27]	SO_2	0.69	0.055*	<0
Balemans 2006[31]	ETS**	1.60	0.025	0.015
Jaakkola 2004[32]	ETS**	1.31		0.045***
Ronmark 2002[33]	ETS**	1.26	0.0085*	0.0022
Lewis 1995[35]	ETS**	1.44	0.038	0.017

PM_{10} Particulate matter with aerodynamic diameter less than 10 μm
$PM_{2.5}$ Particulate matter with aerodynamic diameter less than 2.5 μm
ETS Environmental tobacco smoke
* Overall asthma incidence was used as a surrogate for asthma incidence among unexposed children in studies that did not present enough information to determine the asthma incidence among unexposed children
** Studies for which attributable risk could be determined
*** Reported in the study

Limitations of the studies reviewed

Published Canadian asthma incidence and exposure prevalence data excluded children living in the territories, on reservations, in institutions, and in remote areas. Airborne pollutant exposure was described by summary data rather than threshold levels and standards for indoor pollutant exposures were not found. Some home allergen levels were reported for children with higher socio-economic status because of the difficulty obtaining consent to sample rented or multi-family dwellings.[21,22]

Table 4. Population Attributable Fraction of Asthma Calculated Using Risk Estimates From Cohort Studies and National Asthma Incidence Data*

	Odds Ratio	Attributable Risk	Exposure Prevalence (%)	Population Attributable Fraction (%)			
Age (years)				**0-5**	**6-11**	**12-19 Male**	**12-19 Female**
Asthma incidence (%)				**5.3**	**4.9**	**2.8**	**5.3**
PM_{10}[27]	1.64	0.035	16	11	11	20	11
Outdoor $PM_{2.5}$[28,29]	1.44	0.012	7.1	1.6	1.7	3.0	1.6
Indoor $PM_{2.5}$[28,29]	1.44	0.012	1.7	0.38	0.42	0.73	0.38
Outdoor NO_2[27-29]	1.29	0.0084	25	4.0	4.3	7.5	4.0
Indoor NO_2[27-29]	1.29	0.0084	3.3	0.53	0.57	1.00	0.53
SO_2[27]	0.69	<0	0.022	<0	<0	<0	<0
ETS[33,35]	1.40	0.017	9.0	2.9	3.1	5.5	2.9

* Attributable risk (AR) = the rate of disease among unexposed children x (odds ratio-1) (Formula 2). Population attributable fraction (PAF) = (AR for each exposure x exposure prevalence for each exposure / incidence of asthma within each age group) x 100% (Formula 1a). Odds ratios are presented for comparison.
PM_{10} Particulate matter with aerodynamic diameter less than 10 μm
$PM_{2.5}$ Particulate matter with aerodynamic diameter less than 2.5 μm
ETS Environmental tobacco smoke

Table 5. Population Attributable Fraction of Asthma (%) Using Risk Estimates From Cohort Studies and Provincial Asthma Incidence Data*

	Ontario Administrative Database 2005 (To 2005)		British Columbia All Live Births 1997-2003[3]			Manitoba Population Health Research Repository (1980-90)[4]		
Age (years)	**0-4**	**5-9**	**2-3**	**3-5**	**5-9**	**1**	**2**	**5-6**
Asthma incidence	**3.5****	**1.0****	**2.72****	**2.41****	**1.74****	**2.6*****	**2.9*****	**2.0*****
PM_{10}	16	56	21	23	32	22	19	28
Outdoor $PM_{2.5}$	2.4	8.5	3.1	3.5	4.9	3.3	2.9	4.3
Indoor $PM_{2.5}$	0.58	2.0	0.75	0.85	1.2	0.78	0.70	1.0
Outdoor NO_2	6.0	21	7.8	8.8	12	8.1	7.3	11
Indoor NO_2	0.80	2.8	1.0	1.2	1.6	1.1	0.96	1.4
ETS	4.4	15	5.6	6.4	8.8	5.9	5.3	7.7

* Attributable risk (AR) = the rate of disease among unexposed children x (odds ratio-1) (Formula 2). Population attributable fraction (PAF) = (AR for each exposure x exposure prevalence for each exposure / incidence of asthma within each age group) x 100% (Formula 1a).
** Incident cases per 100 person-years
*** Yearly cumulative incidence (%)
PM_{10} Particulate matter with aerodynamic diameter less than 10 μm
$PM_{2.5}$ Particulate matter with aerodynamic diameter less than 2.5 μm
ETS Environmental tobacco smoke

For airborne pollutants, the cut points for OR calculation were based on individual study percentile or interval changes, rather than on levels of predicted physiological importance. Therefore, the ORs from different studies were not directly comparable and their clinical relevance was more difficult to determine. Most ORs had 95% confidence intervals that spanned 1.00, making it difficult to imply or exclude a contribution to asthma development.

Limitations of the PAF calculation

Most studies examined the risk of asthma development in young children and risks were pooled across age groups, so the differences in PAFs among the age groups depended solely upon the different estimates of asthma incidence. For airborne pollutants and mouse and cockroach allergens, the exposure prevalence cut points were higher than the cut points used to determine ORs, resulting in lower prevalence estimates relative to the AR estimates and possible underestimation of the PAFs. If exposures lower than the WHO airborne pollutant standards or allergen cut points associated with asthma symptoms were required to promote asthma development, the PAFs may also have been underestimated. However, if exposures higher than the WHO standards or allergen cut points were required to promote asthma development, the PAFs may have been overestimated.

The prevalence of mouse (34.5%) and cockroach (26.8%) exposure in the Boston population[37] for which PAFs were calculated using formula 1b were higher than those in the Canadian prevalence studies (17% and 9.8%, respectively),[21,22] possibly resulting in PAF overestimation. However, the prevalence of exposure among Canadian children living in inner city areas may be closer to the Boston estimates than to the Canadian prevalence estimates, which reflect exposures in higher socio-economic status neighbourhoods.

ORs were an appropriate summary measure to use for the systematic review, given the heterogeneous study populations with different event rates and the stable exposure distributions during the studies of incident asthma.[10]

The PAF calculation could not incorporate non-linear associations, such as the higher odds of asthma development in the 4th quintile of dust mite exposure[46] and the 1st and 3rd tertiles of cat and dog exposure,[41] or account for the interactions among exposures and between exposures and genetics.

CONCLUSION

This review suggests that airborne particulates, NO_2, ETS, and mouse and cockroach allergens have positive PAFs for childhood asthma and may contribute to childhood asthma development, although additional studies will be needed to confirm the magnitude of their relative contributions.

Calculation of the PAF stratified by asthma or wheezing phenotype, atopy status and, for ETS, mouse and cockroach, among subgroups of vulnerable children, may help to target specific needs regarding asthma prevention. Studies such as the Canadian CHILD Study[51] are currently underway to sample home allergen levels from a larger population-based sample of homes starting before birth, and should include sufficient numbers to allow stratification.

Recommendations for future validation

Future validation of these conclusions would be aided by the use of global standards associated with the risk of asthma development as cut points for exposure and by the generation of risk estimates from longitudinal studies starting before birth among a represen-

Appendix 1. Population Attributable Fraction (PAF) Formulae and Derivations

		Disease +	Disease -
Exposure	+	a	b
	-	c	d

The derivations are calculated using relative risk, although odds ratios were substituted for these studies with stable exposure distribution.[10]

Formula 1a[8]

$$PAF = \frac{\text{Attributable risk} * \text{Risk factor exposure prevalence}}{\text{Total asthma prevalence}}$$

$$= \frac{[a/(a+b) - c/(c+d)] * (a+b)/(a+b+c+d)}{(a+c)/(a+b+c+d)}$$

$$= [a/(a+b) - c/(c+d)] * (a+b)/(a+c)$$

Formula 1b[9]

$$PAF = \frac{(\text{Relative risk} - 1)}{\text{Relative risk}} * \text{Proportion of cases exposed to risk factor}$$

$$= \frac{\{[a/(a+b)]/[c/(c+d)] - 1\}}{[a/(a+b)]/[c/(c+d)]} * a/(a+c)$$

$$= \frac{\{[a/(a+b)]/[c/(c+d)] - [c/(c+d)]/[c/(c+d)]\}}{[a/(a+b)]/[c/(c+d)]} * a/(a+c)$$

$$= \frac{[a/(a+b) - c/(c+d)]}{[a/(a+b)]} * a/(a+c)$$

$$= [a/(a+b) - c/(c+d)] * (a+b)/(a+c)$$

Therefore, formulae 1a and 1b are algebraically equivalent.

tative cohort of Canadian children. Future analyses should also include evaluation of nonlinear associations, interaction among multiple modifiable environmental risk factors, and interaction between inherited and environmental risk factors.

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Additional references and information are available from the corresponding author upon request.

Received: January 14, 2010
Accepted: August 25, 2010

RÉSUMÉ

Objectifs : Nous avons calculé la fraction attribuable dans la population (FAP) du risque d'asthme chez les enfants au Canada dû aux expositions environnementales modifiables, afin d'estimer la contribution relative de ces expositions au développement de l'asthme, d'après les publications actuelles.

Méthode : Nous avons effectué un examen systématique pour déterminer l'incidence de l'asthme chez les enfants au Canada, la prévalence de l'exposition aux polluants atmosphériques et aux allergènes intérieurs au Canada et les estimations internationales du risque de contracter l'asthme diagnostiqué par un médecin (ADM) associées à chaque forme d'exposition. En combinant les estimations du risque par méta-analyse là où il était possible de le faire, nous avons calculé la FAP selon la formule suivante :

$$\text{FAP} = \frac{\text{Risque attribuable} * \text{Prévalence de l'exposition} * 100\ \%}{\text{Incidence de l'asthme}}$$

Synthèse : L'incidence par âge de l'asthme chez les enfants au Canada se situait entre 2,8 et 6,9 %. Les taux de prévalence des expositions au Canada étaient les suivants : PM_{10} 16 %; $PM_{2.5}$ 7,1 %; NO_2 25 %; fumée secondaire du tabac (FST) 9 %; chats 22 %; chiens 12 %; souris 17 %; blattes 9,8 %; acariens 30 %; humidité 14 %; et moisissures 33 %. Les estimations du risque relatif d'ADM étaient les suivantes : PM_{10} 1,64; $PM_{2.5}$ 1,44; NO_2 1,29; FST 1,40; souris 1,23; blattes 1,96; avec une plage de 1,00 pour les chats, les chiens, les acariens, l'humidité et les moisissures. Les estimations de la FAP relativement aux nouveaux cas d'asthme chez les enfants d'âge préscolaire étaient les suivantes : PM_{10} 11 %; $PM_{2.5}$ 1,6 %; NO_2 4 %; FST 2,9 %, souris 6,5 %; et blattes 13 %.

Conclusion : Selon cet examen systématique, l'exposition aux matières particulaires, au dioxyde d'azote, à la FST, aux souris et aux blattes contribue au développement de l'asthme chez les enfants. Les associations observées semblent plus complexes pour ce qui est des allergènes des chats, des chiens et des acariens et plus variables en ce qui a trait aux moisissures et à l'humidité. Il faudrait mener d'autres études prospectives en population sur le développement de l'asthme chez les enfants, avec des expositions objectivement mesurées, pour mieux chiffrer ces associations.

Mots clés : asthme; enfant; fraction attribuable dans la population; exposition environnementale