Title: Age, period and cohort effects on asthma prevalence in Canadian adults, 1994–2011

Authors:
Sharifa Nasreen MPH MBBS[a,*], Piotr Wilk PhD MSc BSc[a], Tara Mullowney MD[b], Igor Karp PhD MPH MD[a,c]

Affiliation:
[a]Department of Epidemiology and Biostatistics, Western University, London, Ontario, Canada
[b]Department of Pediatrics, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada
[c]Department of Social and Preventive Medicine, School of Public Health, University of Montreal, Montreal, Quebec, Canada

Corresponding author:
Sharifa Nasreen
Department of Epidemiology and Biostatistics,
Schulich School of Medicine and Dentistry, Western University
K201 Kresge Bldg., London, Ontario, N6A 5C1, Canada
E-mail: snasreen@uwo.ca

Abstract

Purpose: To examine the age, period and cohort effects on asthma prevalence among Canadian adults from 1994/1995 to 2010/2011.

Methods: Using data from the National Population Health Survey, 13,616 Canadian adults were followed for 16 years. Age was limited to 18–80 years during follow-up. Modified Poisson regression models with generalized estimating equations were used to estimate age, period and cohort effects on asthma and active asthma prevalence after accounting for socio-demographic factors. Model-based standardization was performed to estimate standardized rates.

Results: Overall asthma prevalence increased from 5% in 1994/1995 to 11% in 2010/2011; decreasing from 12% for 20-year-olds to 6% for 50–60-year-olds and then increased to 8% for 80-year-olds. Individuals aged 20 years had the steepest increase in prevalence between 1994/1995 and 2010/2011. Active asthma prevalence increased from 5% in 1994/1995 to 8% in 2010/2011; decreasing from 8% for 20-year-olds to 5% for 50–60-year-olds and then increased to 6% for 80-year-olds.

Conclusions: Our findings suggest the presence of age, period and cohort effects on prevalence of asthma overall and presence of age and period effects on active asthma prevalence in Canadian adults.

Keywords: Asthma prevalence, age effect, period effect, cohort effect, Canada, adults

List of abbreviations:

CCDSS – Canadian Chronic Disease Surveillance System

ETS – Environmental tobacco smoke

FY – Fiscal year

GEE – Generalized estimating equations

NPHS – National Population Health Survey

SD – Standard deviation

Introduction

Asthma affects an estimated 339 million people globally (1). In Canada, around 2.4 million (8%) persons were estimated to have asthma in 2014 (2). The Canadian Chronic Disease Surveillance System (CCDSS) reported that in 2011–2012 fiscal year (FY), the prevalence of asthma differed by age: decreased from 15% in 20–24 years old to 8.3% in 35–44 years old, remained stable at less than 9% in 45–64 years old before increasing in old age from 9.2% in 65–69 years to 10.6% in 80–84 years. The prevalence of asthma in Canadians aged one year and older increased from 6.5% in 2000–2001 FY to 10.8% in 2011–2012 FY, and during this period the prevalence varied by age (3) suggesting some age-period interaction. The estimated prevalence of asthma with recent symptoms or medication use among Canadians of all ages also increased from 5.1% in 1994 to 6.5% in 2005 (4).

Variation in trends in estimated disease prevalence can be explicated in light of three time-related effects: age, period and cohort effects. Age effect is the change in the frequency of disease occurrence according to age (5), while period effect is the change in the frequency of disease occurrence caused by factors such as health policies and legislations, public health interventions and new treatment that affect all age groups (5, 6). In epidemiology, a cohort effect is conceptualized as a period effect that is differentially experienced across ages (i.e., interaction between calendar time and age) because of differential distribution of environmental or other factors across age groups (7). However, in sociology, a cohort effect is conceptualized as the changes according to the year of birth (birth cohort), irrespective of age and calendar time (6).

Above mentioned results from the CCDSS shed some light on age, period and cohort effects on asthma prevalence, but these effects have yet to be estimated within a formal age, period and cohort analytic framework while accounting for socio-demographic factors. Thus, we carried out a study to examine the effects of age and period on asthma prevalence among

Canadian adults during 1994/1995–2010/2011 FYs and to assess if the period effect differed by age (cohort effect) adopting the epidemiological perspective of cohort effect.

Materials and Methods

Data source

We utilized data from the National Population Health Survey (NPHS), household component conducted by Statistics Canada. Details of the NPHS are available elsewhere (8). Briefly, the NPHS used stratified multi-stage sampling method and included 17,276 individuals aged 12 years or older in 10 Canadian provinces at first cycle in 1994/1995 FY. These respondents were longitudinally followed every two years until cycle 9 in the 2010/2011 FY to collect information on socio-demographic factors, chronic health conditions, lifestyle factors and health services utilization. Response rates decreased from 92.8% in cycle 2 to 69.7% in cycle 9.

Study sample

NPHS participants aged 18–80 years and living in Canada during survey cycles were included in this study. The final analytical sample comprised of 13,616 individuals in cycle 1, 12,334 in cycle 2, 11,296 in cycle 3, 10,364 in cycle 4, 9,391 in cycle 5, 8,593 in cycle 6, 8,205 in cycle 7, 7,194 in cycle 8 and 6,764 in cycle 9 (contributing a total of 87,757 observations).

Outcomes and covariates

Health professional-diagnosed asthma (hereafter asthma) was self-reported by the respondents at each survey cycle. Asthma was ascertained from an affirmative response to the question “We are interested in ‘long-term conditions’ that have lasted or are expected to last 6 months or more and that have been diagnosed by a health professional. Do you have asthma?”

We also used a more conservative definition 'active asthma', which was a binary variable defined as self-reported asthma and one or both of the following conditions: (1) self-reported presence of wheezing, asthma symptoms or asthma attack in last 12 months and (2) intake of asthma medication in the last one month (in the first cycle) or intake of asthma medication in the last 12 months (in the remaining cycles).

Age and period were treated as continuous variables. Covariates controlled for included: sex (male vs. female); province of residence (Atlantic vs. non-Atlantic) (9); country of birth (Canada vs. outside Canada); race (white vs. non-white); educational attainment (less than secondary school graduation, secondary school graduation, some post-secondary and post-secondary graduation); adjusted household income, as categorized by Statistics Canada based on reported total household income in past 12 months and the number of people living in the household (10) (lowest [income <$15,000 and 1–2 persons; <$20,000 and 3–4 persons; <$30,000 and ≥5 persons], lower middle [income $15,000–$29,000 and 1–2 persons; $20,000–$39,000 and 3–4 persons; $30,000–$59,000 and ≥5 persons], upper middle [income $30,000–$59,000 and 1–2 persons; $40,000–$79,000 and 3–4 persons; $60,000–$79,000 and ≥5 persons] and highest [income ≥$60,000 and 1–2 persons; ≥$80,000 and ≥ 3 persons]); exposure to environmental tobacco smoke (ETS) (exposed vs. not exposed) based on current status of household member's regular smoking inside the home, and respondent's smoking status (never, former, current). Covariate information collected at each survey cycle was used, except race and country of birth information that were collected at enrollment.

Missing data

Variable-wise rate of missing data was calculated based on the total observations (87,757) contributed by the respondents across all survey cycles aged 18–80 years during the survey cycles. Among the 87,757 observations, 89% had information on all variables; <1% of observations had missing information on asthma and race; while 2–3% of observations had missing information on educational attainment, exposure to ETS and smoking status. We created a separate household income category for 9.28% of observations with missing information on this variable.

Statistical analysis

Descriptive statistics for covariates at cycle 1 and across survey cycles were calculated as a mean (SD) or percentage. Age was categorized into groups (18–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56–60, 61–65, 66–70, 71–75 and 76–80 years) for descriptive statistics. Prevalence of asthma and active asthma according to age group across the survey cycles were calculated. Modified Poisson regression models with generalized estimating equations (GEE) with autoregressive correlation structure were used to estimate prevalence ratio while accounting for repeated measures (11). Age was centered around its grand mean, and age and an age-squared term were included in the models to allow for potential non-linear relationship between age and both outcomes (12). Cubic age term was considered but excluded because it was not statistically significant for both outcomes and its inclusion in the model decreased model fit. In Model 1, asthma was regressed on age, age^2 and period to estimate age and period effects, and interaction terms between age and period and age^2 and period were included to estimate the cohort effect on asthma. In Model 2, sex, province of residence, country of birth, race, educational attainment, household income, exposure to ETS and smoking status were added to

Model 1 to estimate age, period and cohort effects while controlling for these covariates. These covariates were included as potential confounders in the model because they are known to be associated with asthma (3, 13-16) and availability in the NPHS dataset. Similar models were used for active asthma. We performed sensitivity analysis for active asthma excluding observations from cycle 1 as the recall period for asthma medication intake was one month in cycle 1 compared to 12 months in cycles 2–9.

We performed model-based standardization (17, 18) to estimate standardized prevalence of the outcomes (asthma and active asthma) standardized to the population distribution of the covariates using Model 2. Standardized prevalence was estimated for different scenarios of age (20, 30, 40, 50, 60, 70 and 80 years), period (each survey cycle) and combining age and period (20, 30, 40, 50, 60, 70 and 80 years of age at survey cycles 1 [1994/1995], 5 [2002/2003] and 9 [2010/2011]) with observed covariate values and counterfactual outcomes. Standardized mean prevalence from different age, period and combined age and period scenarios were plotted to depict age, period and cohort (age-period interaction) effects, respectively.

Data analyses were conducted in SAS software v 9.4 (SAS Institute, Cary, North Carolina). GEE was conducted with GENMOD procedure in SAS. Standardized survey sampling weights were used in all analyses.

Results

Socio-demographic characteristics at baseline

At cycle 1, the mean age of the respondents was 43 years, which increased to 55 years in cycle 9. Nearly half of the respondents were male; the majority were born in Canada, were white and did not have exposure to environmental tobacco smoke; 30% were current smoker (Table 1). The mean age across survey cycles was 48 years.

Table 1: Characteristics of respondents at cycle 1, cycle 3, cycle 5, cycle 7 and cycle 9, National Population Health Survey, 1994/1995-2010/2011

Characteristics	**Cycle 1**	**Cycle 3**	**Cycle 5**	**Cycle 7**	**Cycle 9**
	N= 13,616	**N=11,296**	**N= 9,391**	**N=8,205**	**N= 6,764**
Age in years, mean (SD)	43.1 (15.8)	46.3 (15.1)	49.2 (14.2)	52.0 (13.0)	55.1 (12.1)
Male (%)	49.3	49.2	48.7	48.8	48.5
Country of birth, Canada (%)	78.8	79.6	80.1	81.0	81.0
Race					
White (%)	89.6	90.1	90.1	90.6	90.7
Non-white (%)	9.7	9.3	9.3	8.8	8.7
Missing (%)	0.7	0.6	0.7	0.6	0.6
Province of residence, Atlantic (%)	8.2	8.1	8.0	8.5	8.1
Educational attainment					
Less than secondary school graduation (%)	25.1	21.5	17.7	15.4	13.8
Secondary school graduation (%)	16.4	14.8	13.6	13.0	12.5
Some post-secondary (%)	25.7	27.0	25.2	25.0	23.8
Post-secondary graduation (%)	32.5	36.4	39.6	42.3	45.0
Missing	0.3	0.3	4.0	4.3	4.9
Household income					
Lowest income (%)	16.4	10.8	6.9	4.1	3.6
Lower middle income (%)	28.0	24.4	17.4	12.4	10.5
Upper middle income (%)	35.1	36.0	33.1	28.2	24.8
Highest income (%)	15.4	22.7	31.8	41.5	48.4
Missing (%)	5.1	6.2	10.8	14.0	12.8
Exposure to environmental tobacco smoke					
Unexposed (%)	60.7	68.0	75.7	80.8	82.6
Exposed (%)	35.2	30.5	20.6	14.3	12.7
Missing	4.1	1.6	3.7	4.9	4.7
Smoking status					
Never smoked (%)	36.2	34.9	31.4	31.1	30.9
Former smoker (%)	29.5	36.4	42.5	43.8	47.1
Current smoker (%)	30.2	27.3	22.3	20.5	17.8
Missing (%)	4.1	1.4	3.7	4.6	4.3

Asthma prevalence

The prevalence of asthma increased from 5.2% in 1994/1995 to 9.0% in 2010/2011, across all age groups. The prevalence of active asthma also increased from 4.6% in 1994/1995 to 7.0% in 2010/2011 (Table 2).

Table 2: Prevalence of asthma and active asthma among respondents according to age groups across the survey cycles, National Population Health Survey, 1994/1995-2010/2011

Age group, years	**Cycle 1 (1994/1995), N=13596**	**Cycle 2 (1996/1997), N=12329**	**Cycle 3 (1998/1999), N=11289**	**Cycle 4 (2000/2001), N=10310**	**Cycle 5 (2002/2003), N=9313**	**Cycle 6 (2004/2005), N=8534**	**Cycle 7 (2006/2007), N=8114**	**Cycle 8 (2008/2009), N=7125**	**Cycle 9 (2010/2011), N=6718**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Asthma									
18-25	140 (7.2)	101 (7.6)	81 (9.5)	37 (8.9)					
26-30	109 (7.7)	93 (8.2)	78 (8.0)	80 (9.2)	70 (8.0)*	46 (9.4)	21 (11.6)		
31-35	88 (5.0)	107 (7.0)	106 (8.5)	94 (8.9)	73 (8.7)	76 (9.7)	69 (9.5)	55 (10.7)	39 (14.5)
36-40	78 (4.8)	96 (5.9)	94 (5.9)	90 (6.7)	95 (8.6)	87 (9.3)	60 (7.4)	59 (8.8)	69 (11.4)
41-45	50 (3.6)	63 (4.5)	86 (6.3)	105 (7.6)	105 (7.6)	84 (6.9)	95 (8.6)	74 (8.9)	72 (9.9)
46-50	58 (4.7)	63 (5.2)	51 (4.5)	57 (4.8)	70 (6.2)	92 (8.0)	100 (8.5)	86 (7.7)	73 (7.5)
51-55	28 (2.9)	35 (3.7)	62 (6.2)	77 (7.7)	60 (6.0)	71 (7.2)	79 (7.3)	101 (9.8)	92 (8.9)
56-60	39 (4.6)	46 (5.6)	43 (5.5)	44 (5.5)	55 (6.8)	63 (7.6)	75 (8.7)	45 (5.4)	67 (7.4)
61-65	40 (5.3)	38 (5.3)	40 (5.4)	42 (6.1)	49 (7.2)	42 (6.3)	45 (6.6)	58 (8.0)	81 (10.5)
66-70	37 (5.4)	39 (5.9)	48 (8.0)	39 (6.6)	36 (6.4)	36 (6.4)	49 (8.0)	43 (7.5)	42 (7.5)
71-75	27 (4.7)	35 (6.0)	26 (4.7)	37 (7.1)	42 (8.3)	43 (8.6)	34 (7.1)	31 (6.6)	31 (6.2)
76-80	16 (4.5)	20 (5.2)	31 (7.4)	41 (9.1)	30 (7.3)	31 (8.3)	32 (8.2)	36 (9.8)	36 (9.7)
Total	712 (5.2)	735 (6.0)	748 (6.6)	743 (7.2)	685 (7.4)	673 (7.9)	658 (8.1)	588 (8.3)	601 (9.0)
Active asthma									
18-25	123 (6.4)	81 (6.1)	50 (5.9)	30 (7.1)					
26-30	95 (6.7)	69 (6.1)	61 (6.2)	49 (5.7)	46 (5.3)*	30 (6.1)	12 (6.9)		
31-35	82 (4.6)	86 (5.6)	91 (7.3)	72 (6.8)	55 (6.6)	59 (7.6)	55 (7.6)	42 (8.2)	22 (8.4)
36-40	61 (3.8)	74 (4.6)	79 (5.0)	75 (5.6)	81 (7.3)	59 (6.3)	43 (5.3)	46 (6.9)	52 (8.7)
41-45	47 (3.4)	48 (3.5)	71 (5.1)	80 (5.8)	67 (4.8)	63 (5.1)	69 (6.2)	52 (6.3)	54 (7.4)
46-50	44 (3.6)	51 (4.3)	34 (3.0)	47 (4.0)	60 (5.3)	69 (6.0)	79 (6.7)	66 (5.9)	55 (5.6)
51-55	22 (2.3)	26 (2.8)	56 (5.6)	67 (6.6)	44 (4.4)	51 (5.2)	56 (5.2)	70 (6.8)	76 (7.3)
56-60	36 (4.2)	39 (4.7)	37 (4.8)	39 (4.9)	45 (5.6)	56 (6.7)	66 (7.6)	34 (4.1)	51 (5.7)
61-65	39 (5.2)	33 (4.7)	36 (4.9)	36 (5.2)	43 (6.3)	38 (5.7)	36 (5.2)	51 (7.0)	65 (8.5)

66-70	36 (5.2)	34 (5.2)	37 (6.1)	32 (5.4)	29 (5.2)	29 (5.1)	40 (6.5)	36 (6.3)	40 (7.1)
71-75	27 (4.6)	31 (5.3)	24 (4.3)	31 (6.0)	37 (7.5)	38 (7.6)	23 (4.8)	27 (5.9)	25 (5.0)
76-80	16 (4.4)	17 (4.4)	25 (5.9)	35 (7.8)	24 (6.1)	25 (6.6)	27 (7.1)	33 (9.1)	31 (8.3)
Total	630 (4.6)	589 (4.8)	601 (5.3)	592 (5.7)	532 (5.7)	517 (6.1)	506 (6.2)	457 (6.4)	472 (7.0)

[*]18–24 years and 26–30 years age groups combined because frequencies for 18–24 years were not reportable

Age-period-cohort effects on asthma prevalence

Asthma prevalence was negatively associated with age (P = .49) and positively associated with quadratic age (P = <.0001) (Table 3, Asthma, Model 1). There was also a positive association between asthma prevalence and period (P = <.0001). Asthma prevalence was negatively associated with period-age interaction (P = .01) suggesting some cohort effect. Similar results were observed after controlling for covariates (Table 3, Asthma, Model 2).

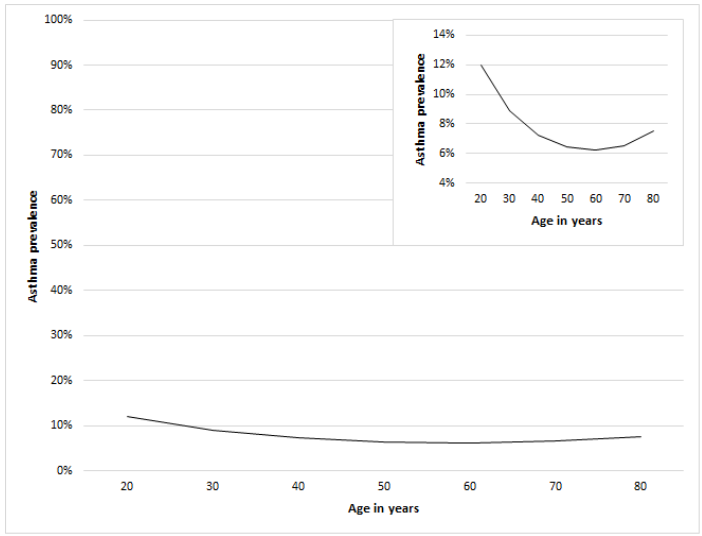
Table 3: Age, period and cohort effects on prevalence of asthma and active asthma among Canadian adults, National Population Health Survey, 1994/1995-2010/2011

	Asthma		**Active asthma**	
	Coefficients (95% confidence intervals)		**Coefficients (95% confidence intervals)**	
	Model 1*	**Model 2†**	**Model 1***	**Model 2†**
Age	-0.0017 (-0.0066, 0.0032)	-0.0038 (-0.0089, 0.0013)	-0.0016 (-0.0068, 0.0037)	-0.0042 (-0.0096, 0.0013)
Age^2	0.0006 (0.0003, 0.0009)	0.0005 (0.0002, 0.0008)	0.0006 (0.0003, 0.0009)	0.0005 (0.0002, 0.0008)
Period	0.0937 (0.0763, 0.1111)	0.0964 (0.0780, 0.1148)	0.0788 (0.0598, 0.0977)	0.0828 (0.0629, 0.1026)
Period*age	-0.0014 (-0.0024, -0.0003)	-0.0011 (-0.0021, 0.0000)	-0.0003 (-0.0015, 0.0009)	0.0000 (-0.0012, 0.0012)
Period*age^2	0.0000 (-0.0001, 0.0000)	0.0000 (-0.0001, 0.0000)	0.0001 (-0.0001, -0.0000)	0.0000 (-0.0001, 0.0000)

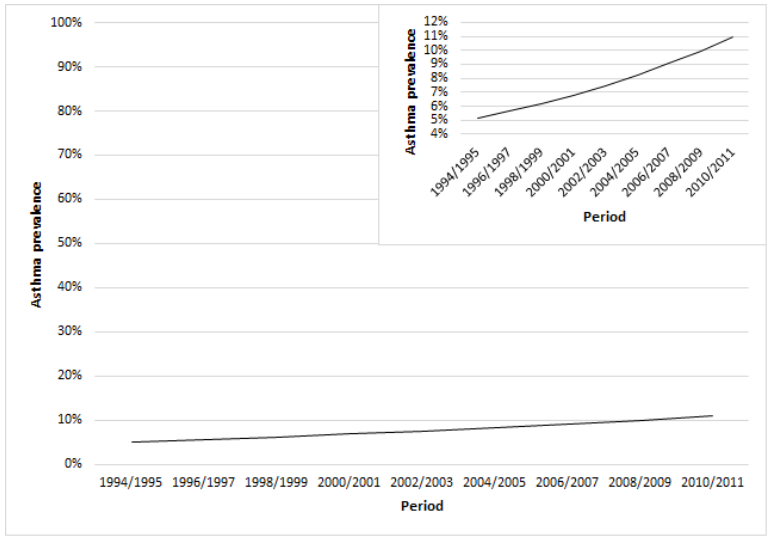
* Unadjusted model

†Adjusted for sex, race, country of birth, province of residence, educational attainment, household income, exposure to environmental tobacco smoke and smoking

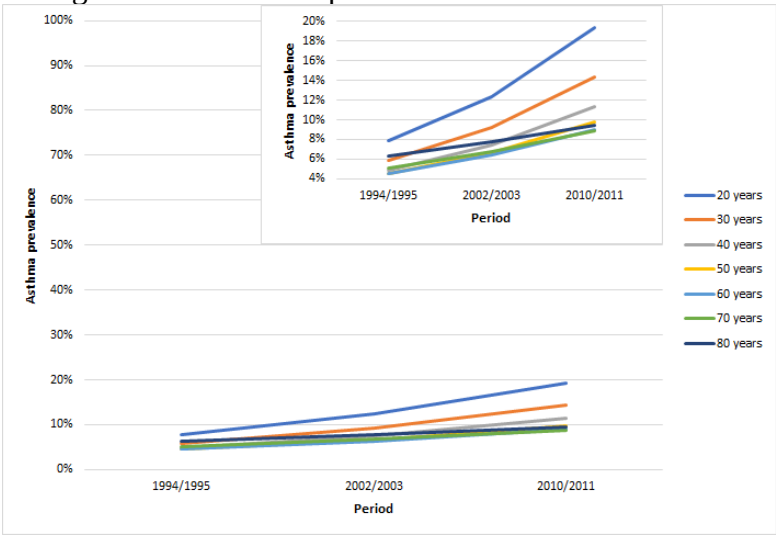
Model-based standardization demonstrated the curvilinear relationship between asthma prevalence and age where asthma prevalence decreased from 12% at 20 years to 6% at 50-60 years and increased thereafter to 8% at 80 years (Figure 1a). There was a gradual increase in asthma prevalence with period from 5% in 1994/1995 to 11% in 2010/2011 (Figure 1b). Period effect differed across individuals of different age (Figure 1c). While asthma prevalence increased between 1994/1995 and 2002/2003, and between 2002/2003 and 2010/2011 for everyone, individuals aged 20 years had the highest asthma prevalence and steepest increase in prevalence across three survey cycles. Individuals aged 80 years had the least increase in asthma prevalence.



1a. Age effect on asthma prevalence



1b. Period effect on asthma prevalence



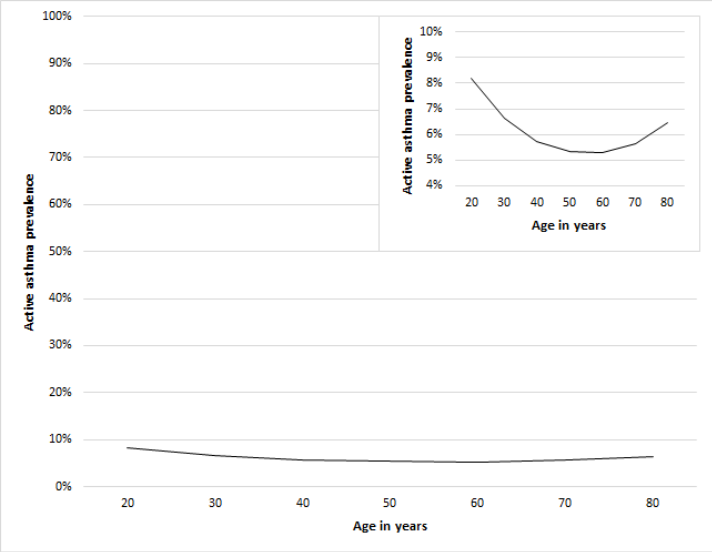
1c. Period effect on asthma prevalence according to age

Figure 1: Model-based standardized prevalence of asthma among Canadian adults, National Population Health Survey, 1994/1995-2010/2011. a: age effect, b: period effect, c: period effect according to age.

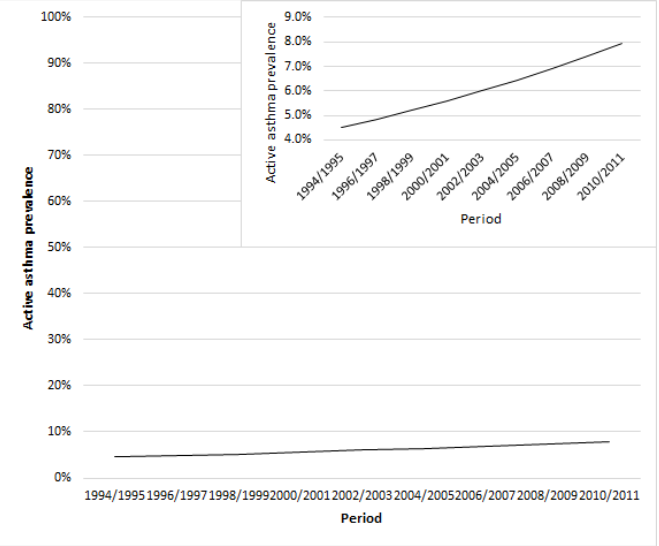
Age-period-cohort effect on active asthma prevalence

Active asthma prevalence was negatively associated with age (P = .56) and positively associated with quadratic age (P = <.0001) (Table 3, Active asthma, Model 1). There was also a positive association between active asthma prevalence and period (P = <.0001). Interaction between period and quadratic age was negatively associated with active asthma prevalence (P = .04) suggesting presence of the cohort effect. After controlling for the covariates, age and period effects on active asthma prevalence remained similar to the results from the unadjusted model (Table 3, Active asthma, Model 2). Period-quadratic age interaction was negatively associated with active asthma prevalence (P = .08). Sensitivity analysis excluding observations from cycle 1 yielded similar results (data not shown).

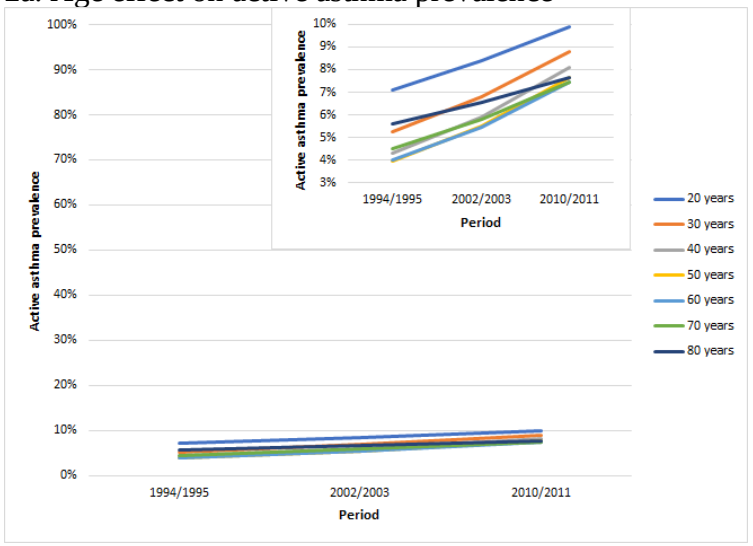
Model-based standardization demonstrated the curvilinear relationship between active asthma prevalence and age where, the prevalence decreased from 8% at 20 years to 5% at 50–60 years, and then increased to over 6% at 80 years (Figure 2a). There was a gradual increase in active asthma prevalence with period from 5% in 1994/1995 to 8% in 2010/2011 (Figure 2b) but was lower and the slope of increase was less steep compared to the slope of increase in prevalence of asthma. The period effect differed across individuals of different age between 1994/1995 and 2002/2003, and between 2002/2003 and 2010/2011 (Figure 2c). Individuals aged 20 years had the highest prevalence across three survey cycles. The increase in active asthma prevalence was least steep in individuals aged 80 years.



2a. Age effect on active asthma prevalence



2b. Period effect on active asthma prevalence



2c. Period effect on active asthma prevalence according to age

Figure 2: Model-based standardized prevalence of active asthma among Canadian adults, National Population Health Survey, 1994/1995-2010/2011. a: age effect, b: period effect, c: period effect according to age.

Discussion

Using a national longitudinal survey, this study examined the age, period and cohort effects on prevalence of asthma, including active asthma, among Canadian adults for 16 years while controlling for socio-demographic factors. Our findings suggest that the prevalence of asthma and active asthma among Canadian adults differed by age (age effect), increased over time (period effect) and the period effect was experienced somewhat differently among individuals of different age during the study period (cohort effect).

The age effect on prevalence of asthma and active asthma, among Canadian adults indicates that the prevalence was highest among young adults, lowest for middle-age adults and then increased slightly in old age. Our finding is similar to the non-model-based estimates from studies that suggested age effect on asthma prevalence among Canadians in 2011–2012 (3), Ontarians during 1996–2015 (19, 20) and the study showing age effect on active asthma prevalence in 2011–2012 (3). However, these studies used administrative data and prevalent asthma was defined as at least two physician visits with a diagnosis of asthma within two consecutive years, or at least one hospitalization with a diagnosis of asthma; active asthma was defined as prevalent asthma with at least one physician visit or asthma hospitalization in a year. Additionally, the time frame of these studies differed from our study, although there was some overlap. The decreasing prevalence of asthma until middle age could be related to a similar relationship between asthma incidence and age. Indeed, in Canadians during 1996 through 2015, asthma incidence decreased with age in young and middle age adults before increasing again in older adults (3, 21). Comparable age effects on asthma incidence have also been observed in Swedish adults (22). Nevertheless, the reduction of asthma incidence has to be substantial to reduce the prevalence in young and middle age adults in our study considering the chronic nature of asthma. It is possible that asthma remained undiagnosed, resulting in a lower prevalence of

asthma in young and middle age adults in our study. Some young and middle-aged adults with asthma in our study remained symptom-free leading to lower prevalence of active asthma compared to older adults. Forty percent of adults aged 18–64 years with asthma in Ontario had two or more years of gaps in asthma activity compared to adults 65 years and older during 15 years of follow-up (23). Different rates of asthma remission have been reported in adults in different settings: 6% in middle aged adults and elderly individuals in Italy (24), 30% in Italian young adults (25), 14.6% in Swedish adults (22) and 18.6% in adults in northern Europe (26). On the other hand, the increased prevalence of asthma, including active asthma in older adults may reflect increased incidence, and uncontrolled or frequent symptomatic asthma with declining lung functions and a low remission rate (27-30), as well as changes in lifestyle and increased access to health care and medication through government funded health care system in Canada. Indeed, age effect can arise from a combination of biological process and social experiences (6).

The prevalence of asthma and active asthma increased over the course of 16 years among Canadian adults in our study, similarly to the temporal trends of asthma prevalence reported previously in Canada (20, 31). The prevalence of 'current asthma', defined as still having asthma among those with a ever diagnosed asthma by a health professional using data from surveys, in adults also increased in the United States from 7.2% in 2000/2001 to 8.5% in 2008/2009 (32). The cause behind this increasing secular trend remains unclear. The increasing prevalence, despite decreasing incidence of asthma (3), and decreased asthma-associated mortality (3, 33), likely reflect better asthma management and the chronic nature of asthma. It is also possible that asthma was over diagnosed because of increased awareness or, in adults 35 years and older, because of 'diagnostic exchange' in the sense that the increased asthma prevalence was driven by a decrease in the prevalence of chronic obstructive pulmonary disease (3, 34). As such, the

increased prevalence would reflect an artifact rather than true increase in asthma prevalence. In our study, across all survey cycles, the prevalence of active asthma was lower than the prevalence of asthma, which is expected as all asthma cases may not experience frequent symptoms or require regular intake of asthma medications. The increasing prevalence has implications for public health policy makers to address health care needs and planning asthma management.

In our study, the increase in prevalence of asthma over time somewhat differed by age, reflected by the unparallel slopes of prevalence for different ages across three survey cycles and steeper slopes in young adults in the graphs with standardized prevalence. However, the difference in period effect according to age was largely attenuated for the restricted definition of active asthma albeit some variation in the slopes for prevalence over period were observed.

Strengths and limitations

The use of data from a population-based longitudinal survey gave us the opportunity to assess the effects of age, period and cohort over a period of 16 years. We were able to adjust for potential confounding by some socio-demographic factors that are not usually available in administrative data. Furthermore, we were able to include more asthma cases, including active asthma cases because medical care delivered by physicians outside fee-for-service and asthma cases not seeking medical care would not be captured by administrative data, including the CCDSS (3). Model-based standardization enabled us to visualize population-wide effect of age and period on prevalence of asthma, including active asthma, and to assess the variation in period effect across different ages using population standardized prevalence.

Asthma diagnosis, symptoms and medication intake were self-reported by the respondents and has the potential for errors in reporting. Compared to respondents with frequent or severe symptoms, respondents with milder symptoms or longer symptom-free periods may underreport which may result in an underestimation of the prevalence of asthma or active asthma. However, inclusion of medication intake in the operational definition of active asthma is expected to minimize misclassification of active asthma by including cases with milder symptoms or longer symptom-free periods because of medication intake. There is a potential for overestimation of active asthma prevalence in cycle 1 because of the shorter recall time for asthma medication between cycle 1 and the remaining cycles. However, we performed a sensitivity analysis excluding observations from cycle 1 and the results were similar. Our study was limited to adults aged 18–80 years. An age cut-point of 80 years was chosen because of fewer respondents with asthma beyond this age and to minimize recall bias. Age, period and cohort effects would vary across different populations and settings and the findings from this study are not generalizable beyond the study period and population.

In conclusion, our findings suggest age and period effects on prevalence of asthma, including active asthma in Canadian adults from 1994/1995 to 2010/2011. The period effect on asthma prevalence was experienced somewhat differently across age groups indicating some cohort effect. Future research is warranted to see whether the age distribution of asthma burden, the rising temporal trend along with the variation in asthma prevalence by age continues beyond our study period and in future.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethics approval

Ethical approval was not needed as the study relied on anonymous and secondary data from Statistics Canada. However, the proposal for this study was approved by the Social Science and Humanities Research Council (SSHRC), Canada to gain access to the data in Statistic Canada's Research Data Centre (RDC) at Western University. The opinions expressed do not represent the views of Statistics Canada.

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