

Original quantitative research

Trends in chronic disease incidence rates from the Canadian Chronic Disease Surveillance System

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Abstract

Introduction: The Public Health Agency of Canada's Canadian Chronic Disease Surveillance System (CCDSS) produces population-based estimates of chronic disease prevalence and incidence using administrative health data. Our aim was to assess trends in incidence rates over time, trends are essential to understand changes in population risk and to inform policy development.

Methods: Incident cases of diagnosed asthma, chronic obstructive pulmonary disease (COPD), diabetes, hypertension, ischemic heart disease (IHD), and stroke were obtained from the CCDSS online infobase for 1999 to 2012. Trends in national and regional incidence estimates were tested using a negative binomial regression model with year as a linear predictor. Subsequently, models with year as a restricted cubic spline were used to test for departures from linearity using the likelihood ratio test. Age and sex were covariates in all models.

Results: Based on the models with year as a linear predictor, national incidence rates were estimated to have decreased over time for all diseases, except diabetes; regional incidence rates for most diseases and regions were also estimated to have decreased. However, likelihood ratio tests revealed statistically significant departures from a linear year effect for many diseases and regions, particularly for hypertension.

Conclusion: Chronic disease incidence estimates based on CCDSS data are decreasing over time, but not at a constant rate. Further investigations are needed to assess if this decrease is associated with changes in health status, data quality, or physician practices. As well, population characteristics that may influence changing incidence trends also require exploration.

Keywords: *administrative data, chronic disease surveillance, trend analysis*

Introduction

Chronic diseases are the leading causes of death and disability worldwide.¹⁻³ Within Canada, age-standardized chronic disease prevalence, the total number of disease cases, has been increasing over time,⁴

whereas age-standardized incidence, the number of new cases, appears to be decreasing for some diseases such as heart disease, stroke, and asthma.⁵⁻¹⁸ This discrepancy may be due to aging of the population, overall growth in the Canadian population or individuals living longer with

the disease. However, disease-specific mortality rates have not been consistently decreasing over time.¹⁹

Estimating population-based trends in prevalence and incidence can be challenging. Longitudinal population-based surveys are one potential source of data on incident and prevalent cases, but they are costly to conduct on a regular basis and

Highlights

- Using data from the Canadian Chronic Disease Surveillance System (CCDSS), national incidence rates were estimated to have decreased over time for diagnosed asthma, chronic obstructive pulmonary disease, hypertension, ischemic heart disease, and stroke, but not for diabetes. Decreasing rates were also observed in many regions of Canada.
- Trends in national and regional chronic disease incidence were often non-linear over time, indicating that the rate of change has not been constant.
- Further research is needed to assess the association of changes in national and regional chronic disease incidence rates with changes in population health, administrative data quality, and/or clinician billing practices.

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are prone to attrition, which can result in inaccuracies in trend estimates. Moreover, survey data do not consistently contain dates relevant to identifying disease onset, such as the date of first diagnosis or the date of treatment.

Administrative health data that capture disease diagnosis information, such as hospital and physician service (i.e., billing) records are routinely collected and therefore often less expensive and timelier to use for prevalence and incidence trend estimation.²⁰ However, changes in data collection methods, coding and classification systems, and clinical and billing practices for chronic diseases can also affect the accuracy of longitudinal trend estimates. As well, the completeness of capture of administrative records for the entire population may change over time, which can result in selection biases. In Canada for example, Newfoundland and Labrador physician service records do not consistently capture patient information from physicians who do not bill on a fee-for-service basis, which disproportionately affects the availability of diagnostic information for rural populations.²¹

One of the routine uses of administrative health data in Canada is for chronic disease surveillance through the Canadian Chronic Disease Surveillance System (CCDSS).²² The CCDSS²³ was created in 2009 to facilitate the collection and reporting of standardized, national estimates of diagnosed chronic disease prevalence, incidence, and health outcomes. It grew out of the National Diabetes Surveillance System (NDSS), which was established in 1999 as a collaborative network of provincial and territorial (P/T) diabetes surveillance systems and supported by Health Canada and then the Public Health Agency of Canada (PHAC).²⁴

In 2016, the CCDSS Data Quality Working Group was formed.²² It conducts ad hoc data quality studies and examines data quality information that arises from a variety of sources, such as case definition validation studies and narrative reports about changes in data coding practices from P/T administrative staff. Trends in incidence and prevalence estimates may be used, in part, to assess data quality.²⁵ Longitudinal trends may be influenced by changes in data quality, in addition to true changes in population health. Unexpected or unexplained changes in trends can

suggest opportunities for follow-up data quality investigations.

To date, there have been few, if any, studies that have tested whether trends in chronic disease incidence from the CCDSS are changing over time. The purpose of our study was to assess incidence trends for multiple chronic diseases at national and provincial/regional levels in the CCDSS and determine if these trends are best captured using a linear effect of time.

Methods

Data source

Data were obtained from the CCDSS online infobase for multiple fiscal years over the period from 1999 to 2012, this was the most recent data available at the time of analysis.²⁶ The infobase includes documentation on CCDSS methods, and the rules used to identify chronic disease cases within administrative databases. We focused on incident cases of disease because incidence is often not available from survey data and is a key measure of population disease risk. Incidence data were obtained for asthma (ages one year and older, 2000–2012), chronic obstructive pulmonary disease (COPD; ages 35 years and older, 2000–2012), diabetes (ages one year and older, 2000–2012), hypertension (ages 20 years and older, 1999–2012), ischemic heart disease (IHD; ages 20 years and older, 1999–2012), and stroke (ages 20 years and older, 2003–2012). The Data Quality Working Group selected these diseases because it was expected they would have trends of different shapes and directions; these diseases affect different body systems and are therefore less likely to move in concert. Data were obtained for the following regions: British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and Atlantic Canada (New Brunswick, Newfoundland, Nova Scotia, and Prince Edward Island). Data from Northern Canada were excluded due to low event rates and the practical challenges with modelling sparse cell sizes. Incidence counts were grouped by age group and sex. CCDSS data are publicly available by five-year or lifecourse age groups. For this analysis five-year age groups were used.

Statistical analysis

Incidence rates were calculated as the number of new disease cases in a year

divided by the total population at risk as of the end of the fiscal year (i.e., March 31st) and expressed per 1000 population. Rates were age standardized using the 2011 Canadian Census population and then described using minimum and maximum values, as well as first year and final year values.

Crude incidence data were subsequently analyzed using multivariable negative binomial regression models. The number of incident disease cases in each year was the outcome. The natural logarithm of the total population for a province or region was the model offset. Model covariates were year, age group, and sex. Age group was included as a cubic covariate based on preliminary assessments of model fit.

This study proceeded in a series of steps to assess trends for each chronic disease and region. The regional data were also combined to assess the trend for Canada as a whole for each chronic disease.

First, a negative binomial model with year as a continuous linear covariate was fit to the data. Next, we applied a series of negative binomial models to the data where year was included as a restricted cubic spline with a truncated power basis. Restricted cubic splines (RCS), or natural splines, are constrained to be linear beyond the boundaries of the first and last knots. The splines are also constrained to have continuous first and second derivatives at each knot, that is, at each location where the piecewise polynomial functions join,²⁷ resulting in a flexible, smooth function. Fitting an RCS to the data allowed us to test for linearity without making any assumptions about the data's overall shape.

Three different RCS models were fit to the data: year as an RCS with five knots, year as an RCS with four knots, and year as an RCS with three knots. Using greater than five knots in an RCS is rarely needed to provide a good fit to the data;²⁸ less than three knots is equivalent to modelling the predictor as a cubic term in the model. Knots were placed at evenly spaced quantiles based on the recommendations by Harrell.²⁷

The Akaike information criterion (AIC)²⁹ was used to assess which RCS model best fit the data. Once the best-fitting RCS model was identified, we used a likelihood

ratio test to determine if the model with year as an RCS fit the data significantly better than the model with year as a linear effect. Statistical significance was assessed using a nominal $\alpha = 0.05$.

Statistical analyses were performed using R software, version 3.4.3 (R Foundation for Statistical Computing, Vienna). The base functions and the Modern Applied Statistics with S (MASS) and Regression Modeling Strategies (rms) packages were used.

Results

Table 1 reports estimated age-standardized incidence rates per 1000 population for each chronic disease and region. These rates are provided for the first and final years of available data. In addition, the minimum and maximum estimates and their respective years are reported.

For Canada, the first and final years of available estimates coincide with the

highest and lowest values, respectively, for asthma, COPD, IHD, and stroke. Estimated age-standardized incidence rates for diabetes increased from 6.60 per 1000 population in 2000 to 7.60 per 1000 population in 2006 (first year of study observation period), then subsequently decreased to 6.17 per 1000 population in 2012, which was both the final year and lowest rate observed. Hypertension age-standardized incidence rates peaked at 32.81 per 1000 population in 2000, which was 0.93 per 1000 population greater than the first year

TABLE 1
Age-standardized incidence rate estimates (per 1000 population), stratified by chronic disease and region

Region	Measure	Asthma		COPD		Diabetes		Hypertension		IHD		Stroke	
		Rate (per 1000)	Year	Rate (per 1000)	Year	Rate (per 1000)	Year	Rate (per 1000)	Year	Rate (per 1000)	Year	Rate (per 1000)	Year
Canada	First year	8.94	2000	12.03	2000	6.60	2000	31.88	1999	12.99	1999	3.83	2003
	Final year	4.74	2012	8.81	2012	6.17	2012	22.29	2012	6.80	2012	2.97	2012
	Minimum rate	4.74	2012	8.81	2012	6.17	2012	22.29	2012	6.80	2012	2.97	2012
	Maximum rate	8.94	2000	12.03	2000	7.60	2006	32.81	2000	12.99	1999	3.83	2003
Atlantic	First year	7.87	2000	13.61	2000	7.51	2000	35.51	1999	13.30	1999	3.82	2003
	Final year	3.96	2012	10.45	2012	7.05	2012	26.60	2012	6.93	2012	2.89	2012
	Minimum rate	3.96	2012	10.45	2012	6.97	2008	26.60	2012	6.93	2012	2.89	2012
	Maximum rate	7.87	2000	13.61	2000	8.01	2006	38.11	2002	13.30	1999	3.82	2003
Quebec	First year	9.11	2000	14.37	2000	6.12	2000	31.92	1999	14.38	1999	3.56	2003
	Final year	4.44	2012	7.03	2012	5.33	2012	18.61	2012	7.34	2012	2.68	2012
	Minimum rate	4.44	2012	7.03	2012	5.33	2012	18.61	2012	7.34	2012	2.67	2011
	Maximum rate	9.11	2000	14.37	2000	6.12	2000	32.02	2000	14.38	1999	3.56	2003
Ontario	First year	10.10	2000	11.04	2000	6.53	2000	31.09	1999	13.25	1999	4.00	2003
	Final year	5.27	2012	8.59	2012	5.91	2012	20.73	2012	6.46	2012	3.00	2012
	Minimum rate	5.27	2012	8.59	2012	5.91	2012	20.73	2012	6.46	2012	3.00	2012
	Maximum rate	10.10	2000	11.04	2000	8.44	2006	32.22	2000	13.25	1999	4.00	2003
Manitoba	First year	8.34	2000	13.76	2000	6.79	2000	29.83	1999	10.73	1999-2000	4.43	2003
	Final year	6.81	2012	8.59	2012	8.21	2012	28.26	2012	6.34	2010-2012	3.25	2012
	Minimum rate	5.56	2011	8.59	2012	6.32	2008	28.26	2012	6.34	2010-2012	3.25	2012
	Maximum rate	8.34	2000	13.76	2000	8.21	2012	31.87	2003	10.73	1999-2000	4.43	2003
Saskatchewan	First year	8.18	2000	10.39	2000	5.91	2000	30.57	1999	11.78	1999	4.24	2003
	Final year	4.72	2012	9.25	2012	6.40	2012	25.43	2012	6.80	2012	3.07	2012
	Minimum rate	4.72	2012	9.11	2011	5.91	2000	25.43	2012	6.80	2012	3.07	2012
	Maximum rate	8.18	2000	10.75	2007	7.29	2006	36.56	2002	11.78	1999	4.24	2003
Alberta	First year	9.06	2000	11.90	2000	6.38	2000	32.78	1999	11.96	1999	3.81	2003
	Final year	5.41	2012	10.46	2012	6.23	2012	27.80	2012	7.14	2012	3.10	2012
	Minimum rate	5.41	2012	10.22	2008	6.16	2003	27.80	2012	7.14	2012	3.10	2012
	Maximum rate	9.06	2000	11.90	2000	6.99	2009	34.75	2001	11.96	1999	3.89	2004
British Columbia	First year	7.32	2000	9.17	2000	6.22	2000	28.03	1999	10.03	1999	3.48	2003
	Final year	4.81	2012	10.15	2012	6.51	2012	21.84	2012	6.18	2012	3.18	2012
	Minimum rate	4.81	2012	7.92	2006	6.22	2000	21.84	2012	6.18	2012	3.18	2012
	Maximum rate	7.32	2000	12.83	2009	7.97	2009	33.25	2006	10.03	1999	3.52	2004

Abbreviations: COPD, chronic obstructive pulmonary disease; IHD, ischemic heart disease.

Notes: Data retrieved August 2018.

Estimated rates are presented only for the first and final years. Minimum and maximum values in the study observation period are also reported.

TABLE 2
Estimated effects of year as a continuous linear covariate (95% CIs) for the negative binomial regression models, stratified by chronic disease and region

Chronic disease	Region	Estimate (95% CI)
Asthma	Canada	-0.05 (-0.06, -0.05) ^a
	Atlantic Canada	-0.06 (-0.07, -0.05) ^a
	Quebec	-0.06 (-0.07, -0.05) ^a
	Ontario	-0.06 (-0.07, -0.05) ^a
	Manitoba	-0.02 (-0.03, -0.01) ^a
	Saskatchewan	-0.05 (-0.06, -0.04) ^a
	Alberta	-0.05 (-0.06, -0.04) ^a
	British Columbia	-0.03 (-0.04, -0.02) ^a
COPD	Canada	-0.02 (-0.02, -0.01) ^a
	Atlantic Canada	-0.02 (-0.02, -0.01) ^a
	Quebec	-0.05 (-0.06, -0.04) ^a
	Ontario	-0.01 (-0.02, -0.01) ^a
	Manitoba	-0.03 (-0.04, -0.02) ^a
	Saskatchewan	-0.01 (-0.02, < 0.00) ^a
	Alberta	-0.01 (-0.01, < 0.00) ^a
	British Columbia	0.03 (0.02, 0.03) ^a
Diabetes	Canada	> 0.00 (< 0.00, > 0.00)
	Atlantic Canada	> 0.00 (< 0.00, > 0.00)
	Quebec	< 0.00 (-0.01, > 0.00)
	Ontario	< 0.00 (-0.01, > 0.00)
	Manitoba	0.01 (> 0.00, 0.01) ^a
	Saskatchewan	0.01 (> 0.00, 0.02) ^a
	Alberta	0.01 (> 0.00, 0.01) ^a
	British Columbia	0.01 (0.01, 0.02) ^a
Hypertension	Canada	-0.02 (-0.02, -0.02) ^a
	Atlantic Canada	-0.02 (-0.02, -0.01) ^a
	Quebec	-0.04 (-0.04, -0.03) ^a
	Ontario	-0.03 (-0.03, -0.02) ^a
	Manitoba	> 0.00 (< 0.00, 0.01)
	Saskatchewan	-0.01 (-0.02, -0.01) ^a
	Alberta	-0.01 (-0.01, < 0.00) ^a
	British Columbia	-0.01 (-0.01, < 0.00) ^a
IHD	Canada	-0.04 (-0.04, -0.03) ^a
	Atlantic Canada	-0.03 (-0.04, -0.02) ^a
	Quebec	-0.04 (-0.05, -0.04) ^a
	Ontario	-0.04 (-0.05, -0.04) ^a
	Manitoba	-0.12 (-0.15, -0.09) ^a
	Saskatchewan	-0.04 (-0.04, -0.04) ^a
	Alberta	-0.02 (-0.03, -0.02) ^a
	British Columbia	-0.03 (-0.04, -0.03) ^a

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(1999), before falling to 22.29 per 1000 population in the final and lowest year (2012). Annual crude rates for each region and disease are available upon request from the authors.

Table 2 provides the estimated effects of year as a continuous linear covariate in the multivariable negative binomial regression models for each region and chronic disease. The estimates indicate the average change in the incidence rate per year, after controlling for age and sex. For Canada, asthma ($-0.05, p < 0.001$), COPD ($-0.02, p < 0.001$), hypertension ($-0.02, p < 0.001$), IHD ($-0.04, p < 0.001$), and stroke ($-0.02, p < 0.001$) all showed a statistically significant decrease in their incidence rates over time. In contrast, there was no statistically significant linear effect of year for diabetes ($0.0007, p = 0.73$).

In terms of the linear effect for the regions (Table 2), there were statistically significant decreases in incidence rates over time for all regions for asthma, COPD, and IHD. For diabetes, there was a statistically significant increase in incidence estimates over time for the western provinces (Manitoba [$0.009, p < 0.001$], Saskatchewan [$0.01, p < 0.001$], Alberta [$0.005, p = 0.03$] and British Columbia [$0.01, p < 0.001$]), but no significant change for the other regions. For hypertension, there was no statistically significant change in incidence over time for Manitoba, but for all remaining regions there were statistically significant decreases. For stroke, there was no statistically significant change in incidence over time for British Columbia, while for all other regions there were statistically significant decreases.

Results from the likelihood ratio test for departures of year from a linear trend are reported in Table 3. Overall, the results show that year departed from a linear trend in numerous regions for many diseases. Stroke incidence was most consistently linear over time, with only Manitoba departing from a linear trend ($\chi^2 = 17.2, df = 2, p < .001$). In contrast, hypertension incidence was non-linear over time for every region except for Manitoba. For Canada, a non-linear incidence trend over time was evident for every disease, except for IHD ($p = 0.692$) and stroke ($p = 0.964$).

Figure 1 reports the national age-standardized incidence rates for all diseases,

TABLE 2 (continued)
Estimated effects of year as a continuous linear covariate (95% CIs) for the negative binomial regression models, stratified by chronic disease and region

Chronic disease	Region	Estimate (95% CI)
Stroke	Canada	-0.02 (-0.02, -0.01) ^a
	Atlantic Canada	-0.02 (-0.03, -0.02) ^a
	Quebec	-0.02 (-0.03, -0.01) ^a
	Ontario	-0.02 (-0.03, -0.01) ^a
	Manitoba	-0.03 (-0.04, -0.03) ^a
	Saskatchewan	-0.04 (-0.04, -0.03) ^a
	Alberta	-0.02 (-0.02, -0.01) ^a
	British Columbia	< 0.00 (-0.01, 0.01)

Abbreviations: COPD, chronic obstructive pulmonary disease; IHD, ischemic heart disease.

Note: Estimates are adjusted for age and sex.

^a Statistically significant at $\alpha = 0.05$.

illustrating the nature of the decreasing trend over time. Diabetes incidence generally increased before beginning to decrease in 2009. Inconsistent changes in incidence rates can be observed over time for diseases where the models with year as an RCS indicated that the national data did not have a linear effect of time (e.g., asthma, COPD, diabetes, and hypertension). For example, COPD incidence displays a mildly cubic shape and hypertension incidence has a slightly quadratic shape, where decreases in incidence rates are minimal at first and begin to increase as time progresses. In contrast, both IHD and stroke show little deviation from a linear trend, as indicated by the spline model results.

Discussion

Our study assessed Canadian chronic disease incidence rates over time and determined if the trends were best captured by modelling time (i.e., year) as a linear effect. Results from the models with a linear time effect showed that chronic disease incidence rates are slowly decreasing for all diseases except diabetes; however, in many cases, allowing for departures from linearity significantly improved model fit. Therefore, to fully understand the changing patterns of chronic disease incidence within and across Canada, researchers should consider using time as a non-linear factor to summarize and explain chronic disease incidence rates.

Previous Canadian studies^{4-9,11,12,30-33} about chronic disease incidence rates have described changes in incidence rates as absolute or relative differences between the first and last years of the study period, ignoring the rate patterns in the interim. Exceptions to this are two studies exploring the incidence rates of type one¹⁵ and type two¹⁶ diabetes in British Columbia. These studies analyzed the overall annual percent change in incidence rates and reported the years in which significant changes in rates occurred. Results from both studies indicate that changes in diabetes incidence rates were not constant over time and could not be fully described using the difference between the first and last years of observation.

Based on our findings, incidence rates demonstrate an overall downward trend for all diseases except for diabetes. These findings are consistent with findings from other studies that have examined chronic

TABLE 3
Fit of the negative binomial regression models with year as restricted cubic spline containing three, four, and five knots and tests for departures of year from a linear trend, stratified by chronic disease and region

Chronic disease	Region	AIC values			Test for departure from linear trend		
		5 knots	4 knots	3 knots	χ^2	df	p-value
Asthma	Canada	7686.3	7685.2	7683.6 ^a	5.2 ^b	1.0 ^b	0.023 ^b
	Atlantic	2020.5	2018.6	2016.8 ^a	0.2	1.0	0.694
	Quebec	2386.2	2383.9 ^a	2384.3	6.2 ^b	2.0 ^b	0.046 ^b
	Ontario	2565.1	2564.8	2564.8 ^a	3.9 ^b	1.0 ^b	0.049 ^b
	Manitoba	1862.1	1861.9 ^a	1864.3	31.4 ^b	2.0 ^b	< 0.001 ^b
	Saskatchewan	1777.6	1775.6	1773.6 ^a	0.1	1.0	0.791
	Alberta	2123.0	2121.6	2120.8 ^a	8.1 ^b	1.0 ^b	0.005 ^b
	British Columbia	2192.8	2191.5 ^a	2193.5	5.2	2.0	0.074
COPD	Canada	4659.2 ^a	4664.7	4683.8	50.2 ^b	3.0 ^b	< 0.001 ^b
	Atlantic	1445.6	1445.2	1445.2 ^a	0.0	1.0	0.933
	Quebec	1644.3	1643.4 ^a	1645.6	14.7 ^b	2.0 ^b	< 0.001 ^b
	Ontario	1744.5	1743.3 ^a	1746.0	7.8 ^b	2.0 ^b	0.020 ^b
	Manitoba	1242.9	1242.8	1241.8 ^a	4.4 ^b	1.0 ^b	0.037 ^b
	Saskatchewan	1238.4	1237.3	1235.9 ^a	2.0	1.0	0.159
	Alberta	1420.5	1419.6	1417.6 ^a	2.1	1.0	0.152
	British Columbia	1469.5 ^a	1489.2	1517.7	63.1 ^b	3.0 ^b	< 0.001 ^b
Diabetes	Canada	7019.3	7017.7 ^a	7019.2	30.1 ^b	2.0 ^b	< 0.001 ^b
	Atlantic	1832.9 ^a	1836.1	1834.4	7.0	3.0	0.074
	Quebec	2191.3	2190.1	2188.6 ^a	2.2	1.0	0.142
	Ontario	2406.1	2404.9 ^a	2407.3	45.5 ^b	2.0 ^b	< 0.001 ^b
	Manitoba	1677.1 ^a	1677.9	1686.3	22.0 ^b	3.0 ^b	< 0.001 ^b
	Saskatchewan	1640.2	1638.9 ^a	1640.8	17.0 ^b	2.0 ^b	< 0.001 ^b
	Alberta	1920.4	1918.6	1917.7 ^a	2.4	1.0	0.123
	British Columbia	1995.6 ^a	1995.9	2003.0	36.1 ^b	3.0 ^b	< 0.001 ^b

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TABLE 3 (continued)
Fit of the negative binomial regression models with year as restricted cubic spline containing three, four, and five knots and tests for departures of year from a linear trend, stratified by chronic disease and region

Chronic disease	Region	AIC values			Test for departure from linear trend		
		5 knots	4 knots	3 knots	χ^2	df	p-value
Hypertension	Canada	6606.8	6606.1	6605.3 ^a	70.0 ^b	1.0 ^b	< 0.001 ^b
	Atlantic	1937.1	1936.8	1936.3 ^a	33.3 ^b	1.0 ^b	< 0.001 ^b
	Quebec	2245.0	2243.3	2242.2 ^a	8.6 ^b	1.0 ^b	0.003 ^b
	Ontario	2373.0	2371.5	2370.5 ^a	34.4 ^b	1.0 ^b	< 0.001 ^b
	Manitoba	1770.6 ^a	1771.1	1771.1	4.6	3.0	0.206
	Saskatchewan	1734.9 ^a	1736.9	1739.5	55.9 ^b	3.0 ^b	< 0.001 ^b
	Alberta	2066.3	2065.1 ^a	2065.9	8.1 ^b	2.0 ^b	0.018 ^b
	British Columbia	2086.7	2084.2 ^a	2095.8	80.4 ^b	2.0 ^b	< 0.001 ^b
IHD	Canada	6213.3	6212.9	6211.0 ^a	0.2	1.0	0.692
	Atlantic	2017.7	2017.1	2015.9 ^a	6.9 ^b	1.0 ^b	0.008 ^b
	Quebec	2045.7	2044.0	2042.4 ^a	2.5	1.0	0.116
	Ontario	2233.8 ^a	2235.8	2234.1	5.6	3.0	0.131
	Manitoba ^c	636.0	634.2	634.3 ^a	4.6 ^b	1.0 ^b	0.032 ^b
	Saskatchewan	1437.2	1435.3	1433.8 ^a	1.7	1.0	0.195
	Alberta	1825.7	1824.3 ^a	1825.4	3.5	2.0	0.173
	British Columbia	1774.8 ^a	1777.5	1778.8	14.2 ^b	3.0 ^b	0.003 ^b
Stroke	Canada	3736.4	3734.4	3732.6 ^a	0.002	1.0	0.964
	Atlantic	977.8	975.7	974.3 ^a	0.9	1.0	0.357
	Quebec	1306.4	1304.5	1302.6 ^a	0.9	1.0	0.351
	Ontario	1389.3	1387.5	1385.5 ^a	1.1	1.0	0.290
	Manitoba	922.8	920.3 ^a	922.4	17.2 ^b	2.0 ^b	< 0.001 ^b
	Saskatchewan	896.6	894.8	892.9 ^a	1.6	1.0	0.203
	Alberta	1051.7	1051.2	1049.3 ^a	0.04	1.0	0.834
	British Columbia	1146.0	1145.1 ^a	1147.2	4.2	2.0	0.120

Abbreviations: AIC, Akaike information criterion; COPD, chronic obstructive pulmonary disease; IHD, ischemic heart disease.

Note: Models adjusted for age and sex.

^a Indicate which RCS model was compared to the model with year as a linear predictor.

^b Statistically significant at $\alpha = 0.05$.

^c Used 3 knots to test instead of 4 since limited improvement in fit with 4 knots.

disease incidence rates within Canada using administrative health data. However, previous studies have not necessarily assessed incidence trends over the same period as was used in our study, so comparisons should be made with caution. Age- and sex-standardized stroke hospital admissions rates across Canada dropped by 0.74 per 1000 population between 1994 and 2004⁶ and 0.227 per 1000 population between 2003 and 2013.⁵ Age- and sex-standardized asthma incidence rates in Ontario increased between 1996–1997 and 2000–2001 then remained stable to 2004–2005 among children 14 years and younger while older age groups showed declines ranging from 0.4 to 1.3 per 1000 between 1996 and 2005.¹⁴ In Ontario, age- and

sex-standardized concurrent asthma and COPD incidence rates decreased by 0.4 per 1000 from 2002 to 2012 and age- and sex-standardized COPD incidence rates decreased by 3.3 per 1000 from 1996 to 2007.^{7,8} Alberta age- and sex-standardized COPD incidence also decreased from 2002 to 2010,¹⁰ and age-standardized incidence rates decreased by 5.1 per 1000 between 2001 and 2011 in Quebec.⁹ Heart disease incidence rates (age-standardized) decreased in Quebec and Canada overall by approximately 5.6 per 1000 between 2000 and 2013,¹² and 5.5 per 1000 from 2000–2001 to 2012–2013,¹³ respectively. Age-standardized heart failure incidence decreased in Ontario by 1.49 per 1000 between 1997 and 2007.¹¹ In contrast, diabetes incidence

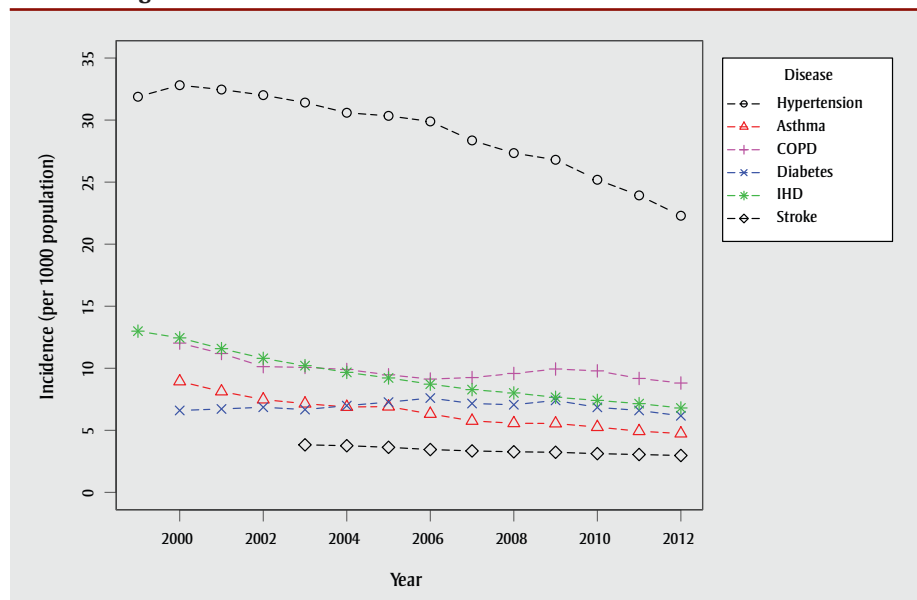
appears to be increasing in Alberta (1995–2006; age- and sex-adjusted) and Ontario (1997–2003; age- and sex-adjusted) but a variable trend among youth and children in British Columbia (2002–2003 to 2012–2013; age-standardized).^{15–18}

Potential reasons for the overall decline in chronic disease incidence may include lower prevalence of modifiable risk factors⁴ and improved prevention strategies.^{34,35} Differences in incidence patterns between regions could, in part, be due to differences across provinces in the strategies used to address chronic disease and risk factor management.³⁶

The decrease in hypertension, stroke, and IHD incidence for Canada is consistent with a decrease in mortality rates for cardiovascular-related diseases, including IHD, acute myocardial infarction, and heart failure.^{13,19} Other diseases, such as COPD, do not exhibit consistent trends in mortality rates,¹⁹ suggesting disease treatment may also play a role in the relationship between incidence and mortality rates. For diseases with a shorter average time between detection and death, such as stroke, mortality rates may be more indicative of changing incidence rates, rather than changes in treatment.

CCDSS methods for using administrative data to capture disease incidence have been validated for several chronic diseases, including asthma, COPD, IHD, hypertension, and diabetes.^{37–41} The first date of disease diagnosis is used in administrative data as a proxy for disease onset. Incidence trends captured by the CCDSS can provide valuable insights into changes in Canadian population health; however, they may be influenced by changes in administrative data quality, such as modifications in data collection methods, coding and classification systems, or billing practices. For example, an increase in the number of healthcare practitioners paid by salary who submit administrative data via shadow-billing rather than the traditional fee-for-service method may increase the number of missing diagnoses codes.²¹ Changes in clinical practice and screening and diagnoses criteria also likely influence trends in chronic disease incidence captured by the CCDSS over time. Moreover, incentive programs within different regions, such as the British Columbia Chronic Disease Incentive Program implemented in April 2006, may also erroneously influence

FIGURE 1
Age-standardized chronic disease incidence rate estimates for Canada



Abbreviations: COPD, chronic obstructive pulmonary disease; IHD, ischemic heart disease.

incidence trends, where better healthcare access and continuity of care result in increased disease detection within the first years after program implementation.⁴² Factors influencing administrative data and its collection should be considered when interpreting incidence rates obtained from the CCDSS.

There are several benefits to using CCDSS data to examine chronic disease incidence within Canada. Previous studies^{4,7-12,14-18,31-33,43} have only looked at diseases within one region of Canada. With CCDSS data, trends can be examined for Canada as a whole, as well as for different Canadian regions, using publicly available data. There is also good validity to compare the trends within different regions of Canada, as data were obtained using uniform case ascertainment methods. Moreover, CCDSS data can be used to assess longitudinal trends without interruption; national longitudinal survey data are often collected in waves with no available data for the years between waves.

While our analysis allowed us to determine if significant departures from linearity occurred for the time effect, it did not allow us to assess where the departures occurred. Such information would be beneficial to inform if, and how, specific changes in health policy (i.e., access to healthcare, physician reimbursement policies, billing practices), risk factors, and

intervention efforts are related to disease incidence.

Future research could examine factors influencing changing incidence of chronic disease over time across Canada. Chronic disease incidence rates estimated from administrative data may be influenced by changes in population health status, clinical diagnostic and screening practices, or administrative practices within provinces, such as physician billing methods. Future analyses could focus on incidence estimates for other chronic diseases that are now a part of the CCDSS, including osteoporosis, depression, and osteoarthritis. The CCDSS Data Quality Working Group plans to explore incidence trends within Canada's P/Ts and conduct data quality surveys to help ascertain how much changing trends are due to changes in administrative practices or changes in population health.

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Conflicts of interest

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Authors' contributions and statement

All authors conceived the idea for the study. NCH and LT conducted the analyses. NCH, LML, JE, and LP prepared the draft manuscript. All authors reviewed and approved the final manuscript for submission.

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