Changing rates of mortality and hospitalization for non-intentional non-fire related carbon monoxide poisoning across Canada

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Background: Carbon monoxide (CO) is a leading cause of accidental poisoning. However, the epidemiology of mortality and morbidity from non-intentional non-fire related CO poisoning in Canada has as yet received little attention.

Methods: Age- and sex-standardized mortality (1981 to 2009) and hospital admission (1995 to 2010) rates by age group, gender, and place of CO exposure were calculated for Canadian provinces and for Canada as a whole. We quantified the long-term trends by calculating the average annual percent change (AAPC). Multivariable Poisson regression was used to estimate incidence rate ratios (IRRs) of CO poisoning across age groups, sex and month.

Results: In Canada, between 1981 and 2009, there were 1,808 non-intentional non-fire related CO poisoning deaths and 1,984 hospitalizations between 1995 and 2010. Average annual decreases of 3.46% (95% confidence interval [CI] -4.59% to -2.31%) and 5.83% (95% CI -7.79% to -3.83%) were observed for mortality rates and hospitalization rates, respectively. Mortality (IRR = 5.31, 95% CI 4.57 to 6.17) and hospital admission (IRR = 2.77, 95% CI 2.51 to 3.03) rates were elevated for males compared to females. Decreased trends in rates were observed for all places of CO exposure, but the magnitude of this decrease was lowest in residential environments. Deaths and hospitalizations were most frequent from September to April with peaks in December and January.

Interpretation: Mortality and hospitalization rates for non-intentional non-fire related CO poisoning in Canada have declined steadily. Continued efforts should focus on reducing CO poisoning during the cooler months and in residential environments.

Introduction

Non-intentional non-fire related CO poisoning is a leading cause of accidental poisoning in the United-States [1]. Exposure to CO occurs mostly in indoor home environments through malfunctioning home heating systems, the operation of gasoline-powered equipment in enclosed or semi-enclosed areas and improperly vented gas appliances [2, 3]. Inhalation of CO can result in reduced oxygen transport by the blood, a condition that starves the body's cells and organs. The adverse effects associated with CO poisoning vary depending on the level and duration of exposure, and range from minor flu-like symptoms and shortness of breath to confusion, unconsciousness, coma and death [4].

Since 1968, studies have shown a decrease in rates of non-intentional non-fire related CO poisoning mortality and/or hospitalization in the United-States [5-7] and in the United-Kingdom [8], while increasing or stable CO poisoning mortality rates have been observed in other European countries [9]. Whether rates of non-intentional non-fire related CO poisoning mortality and/or hospitalization have been changing in Canada has not been described. In addition, few US or European studies have provided magnitude estimates of the changes over time in CO mortality and/or hospitalization and few investigations have evaluated long-term trends in rates as a function of the place of occurrence of CO exposure [7, 8, 10]. Finally, little is known about who in Canada is poisoned by CO, where and when.

The aim of this study was to evaluate trends in the rates of mortality and hospital admissions for non-intentional non-fire related CO poisoning across Canada including analysis by province, age, sex, and month and place of occurrence of CO poisoning.

Methods

Data sources

Mortality data

We accessed Statistics Canada's Vital Statistics Death Database in order to obtain national data on deaths related to non-intentional non-fire related CO poisoning from January 1, 1981 to December 31, 2009 [11]. The International Classification of Diseases (ICD) ninth (1981 - 1999) and tenth revisions (2000 - 2009) [12] were as the basis for extracting non-intentional non-fire related CO poisoning deaths. We excluded intentional (i.e. suicide, assault) and fire-related CO poisoning from our analysis because the public health prevention strategies for these conditions differ from non-intentional non-fire related CO exposures [5]. We extracted deaths where the primary or secondary cause of death was associated with accidental non-fire related CO poisoning using the following codes: ICD-10 codes X47 or ICD-9 codes E867, E868.0, E868.1, E868.2, E868.3, E868.8, E868.9 [13, 14]. Extracted deaths also had to provide a supplementary code to characterize death associated with CO poisoning using ICD-10 code T58 or ICD-9 code 986 related to the ‘Toxic effect of carbon monoxide’ [9]. Information on gender, age at death, province of occurrence of death and place of CO poisoning occurrence was also extracted. The latter was categorized as the following: home/residential, occupational, recreational/sports, public areas and other/unknown [5].

Hospital admission data

CO-related poisoning hospitalizations for the period of January 1995 to December 2010 were extracted from the Hospital Morbidity Database of the Canadian Institute for Health Information [15]. Non-intentional non-fire related CO poisoning hospitalizations were extracted if ICD-10 code "T58" or ICD-9 code "986" was listed in any diagnosis (e.g. most responsible diagnosis, secondary, tertiary, etc.) fields [5]. We used the same ICD-9 and ICD-10 codes mentioned previously to identify accidental non-fire related CO poisoning cases. Data on sex, age at hospitalization, province of occurrence, and place of CO poisoning were extracted from the hospital database. Using an encrypted health card number for each patient, we excluded admissions which were compatible with the transfer of patients between hospitals.

Statistical analysis

We calculated age- and sex-standardized rates of death and hospitalization per million population for each year of the corresponding time periods. The number of CO-related deaths and hospitalizations were divided by the size of the corresponding Canadian population that year, as determined from the Canadian censuses. Age- and sex-standardized rates were obtained through direct standardization to the 1991 Canadian population, the standard reference population recommended by Health Canada for disease surveillance [16]. CO poisoning death and hospitalization rates were calculated nationally, by province, sex, age group (≤ 14, 15 – 24, 25 – 34, 35 – 44, 45 – 54, 55 – 64, 65 – 74 and ≥ 75) and place of CO poisoning occurrence.

Temporal trends in the age- and sex-standardized rates of death and hospitalization for the corresponding time periods were expressed as the Annual Average Percent Change (AAPC) with 95% confidence interval (CI). In this type of analysis, a Poisson regression model was conducted using the standardized rates as the dependent variable and the year of death or hospitalization as the independent variable. The AAPC is calculated from the β of the regression slope of log rates on year (AAPC = [eβ – 1] × 100). This approach estimates the magnitude of the increase or the decrease in rates observed over time. A Poisson regression model was also conducted to evaluate the determinants of CO poisoning adjusting for the following variables: age group, sex, month of occurrence and year of occurrence. Incidence rate ratios (IRRs) were obtained for these models. The analyses were conducted using SAS, version 9.3.

Results

Between 1981 and 2009, there were 1,808 non-intentional non-fire related CO poisoning deaths in Canada (Table 1). In comparison, between 1995 and 2010 there were 1,984 hospitalizations. We observed a 3.46% (95% CI -4.59% to -2.31%) average annual decrease in age- and sex-standardized death rates overall for Canada during the study period (1981 – 2009). A steady reduction in annual hospitalization rates was also observed for the time period of 1995 to 2010 (AAPC = -5.83% [95% CI -7.79% to -3.83%]). Non-intentional non-fire related CO poisoning mortality and hospitalization rates decreased over time for both males and females, although the rates remained higher for males (Figures 1 and 2).

Analyses stratified by Canadian province are shown in Table 1. The greatest reductions in mortality and hospitalization were seen in Saskatchewan (AAPC = -29.48% [95% CI -37.38% to -20.61%]) and New-Brunswick (AAPC = -23.76% [95% CI -39.19% to -4.44%]), respectively. Average annual mortality rates were highest in the three Prairie Provinces (Alberta, Saskatchewan and Manitoba). In addition, greater variation in average annual rates of hospitalization by province was observed compared to mortality rates by province.

As shown in Figures 1 and 2, accidental non-fire related CO poisoning mortality and hospitalization rates have decreased significantly over time in both males and females, but the magnitude of these decreases differs across age groups (Table 2). Men aged 25 to 44 had the highest average annual CO poisoning hospitalization and mortality rates.

The most common place of occurrence of non-intentional non-fire related CO poisoning was at home. The average annual rates of mortality and hospitalization for CO exposure at home were 1.17 and 1.82 per million population, respectively (Table 3). These were more than double the rates observed for the other places of occurrence. When excluding other or unknown places of occurrence, CO poisoning at home represented the lowest AAPC observed for mortality (AAPC = -5.09% [95% CI -6.46 to -3.68]) and hospitalization (AAPC = -2.51% [95% CI -5.31 to 0.34]).

The investigation of the determinants of CO poisoning showed that males have significantly elevated rates of mortality (IRR = 5.31, 95% CI 4.57 to 6.17) and hospital admission (IRR =

2.77, 95% CI 2.51 to 3.03) compared to females (Table 4). Statistically significant increased rates of CO poisoning hospitalization (from September to March) and mortality (from October to April) were observed when compared to rates in August (Figure 3).

Interpretation

This study showed that non-intentional non-fire related CO poisoning mortality and hospitalization rates have been decreasing steadily in Canada over the past decades. Several Canadian provinces showed steady linear reductions in CO poisoning death and hospitalization rates. While rates have declined among both males and females, rates for males have been and remain higher. Rates for all places of occurrence of CO poisoning decreased over time, but the magnitude of the decrease for CO poisoning occurring in home/residential environments was the lowest, excluding other/unknown places. In addition, CO poisoning occurred mostly from September to April with peaks during the winter period.

Decreasing mortality and hospitalization rates reflect the tendency observed in other developed countries [1, 8, 9]. This decrease could be related to several factors. For instance, there may be improvements in the design, use and maintenance of home products and vehicles susceptible to release CO. In particular, the introduction of catalytic converters in vehicles resulted in decreased carbon monoxide emissions [17]. Increased awareness of the adverse health effects of accidental CO poisoning either through prevention programs or media coverage of fatal CO poisoning cases may also explain these findings. In addition, medical care for patients with CO poisoning likely improved over time. The use of CO alarms in homes likely reduced the number of CO poisoning cases. However, a recent Home Safety survey conducted across Canada showed that 60% of Canadians do not have a CO alarm at home [18]. Canadian males had the highest CO mortality and hospitalization rates which is consistent with previous studies [1, 8, 9]. There may be behavioral factors that could explain these findings such as the fact that men may be more likely to use combustion appliances inappropriately and/or without appropriate ventilation [19]. The fact that the rates were highest for CO poisoning occurring in home/residential environments is consistent with previous reports from the United Kingdom and the United States, although the magnitude of the trends was not reported in these studies [7, 8]. Our results suggest that continued efforts should focus on educating Canadians on how to prevent CO poisoning in home/residential environments. Finally, CO poisoning seems to occur mostly during the cooler months in Canada, as previously reported for the U.S. [20]. Vehicle exhaust systems or home heating vents may become obstructed with snow causing accumulation of carbon monoxide in homes or inside the passenger compartment of a vehicle [21].

Strengths and limitations

Strengths of our study include the use of national health administrative databases allowing analyses by province, age group, sex, and place of occurrence of CO poisoning. Also, the temporal resolution of the data allowed us to describe the monthly distribution of CO poisoning.

Our study has several limitations. Among them, due to a lack of availability of information in the administrative data studied, we could not assess specific mechanisms and/or consumer products through which non-intentional non-fire related poisoning occurred. The small number of events reported for some provinces and territories affected the statistical power to detect trends in rates over time for these jurisdictions. The great variation observed in average annual rates of hospitalization by province compared to mortality rates suggests a lack of consistency across provinces in coding for CO poisoning. Finally, this study relied only on hospitalization rates to assess trends in non-fatal CO poisoning which is not optimal given that persons hospitalized for CO poisoning are among the most severely poisoned cases. Alternatively, the use of poison control centre calls or emergency department data for non-fatal CO poisoning cases should be considered in public health surveillance systems [22, 23]. However, these data were not available across Canada.

Conclusions

Non-intentional non-fire related CO poisoning mortality and hospitalization rates have been decreasing over time in Canada. However, continued efforts should focus on reducing CO poisoning among males, during the cooler months and implementing appropriate measures to prevent CO poisoning at home such as supporting heating and cooking product design to improve combustion safety, and encouraging the use of home CO detectors.

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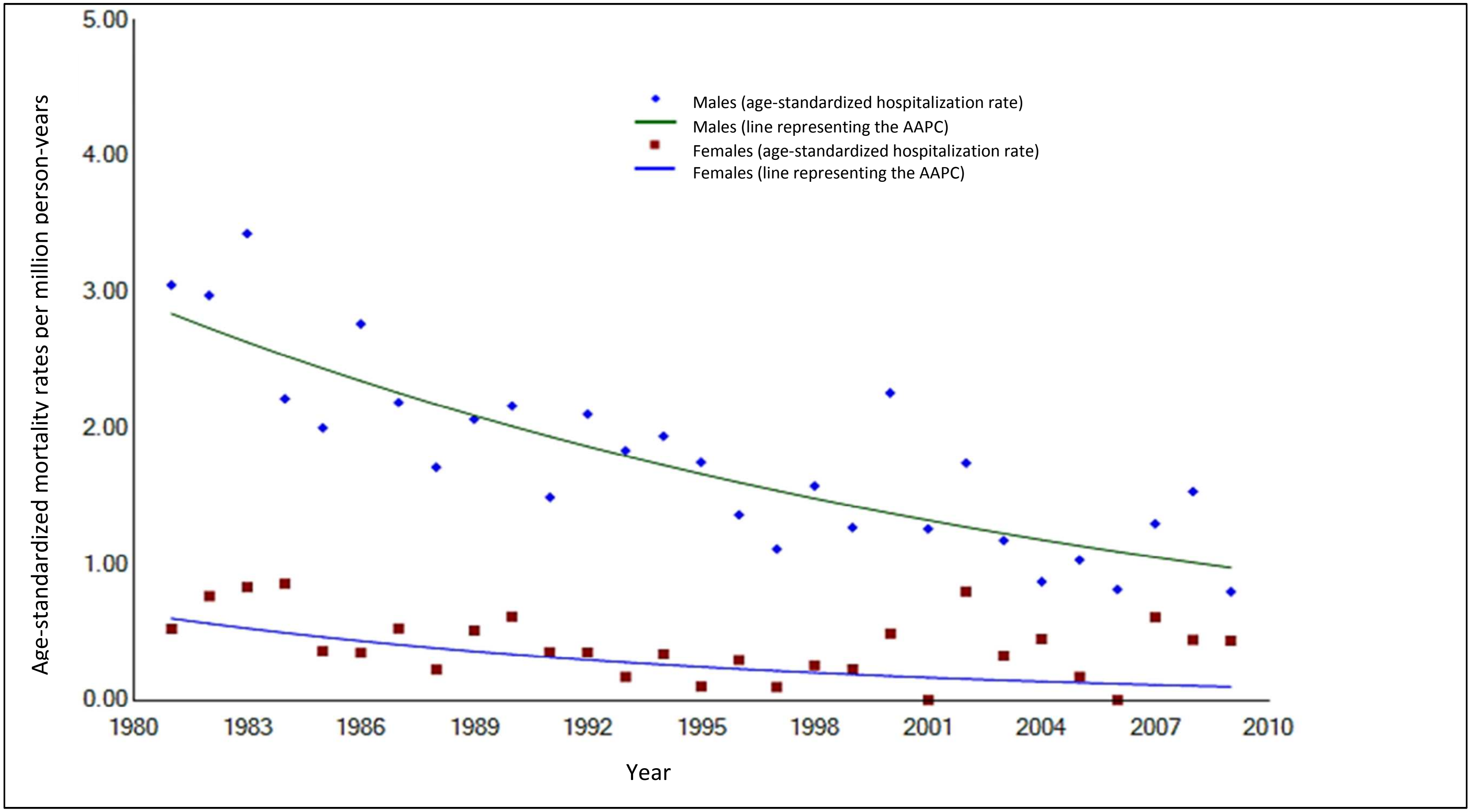
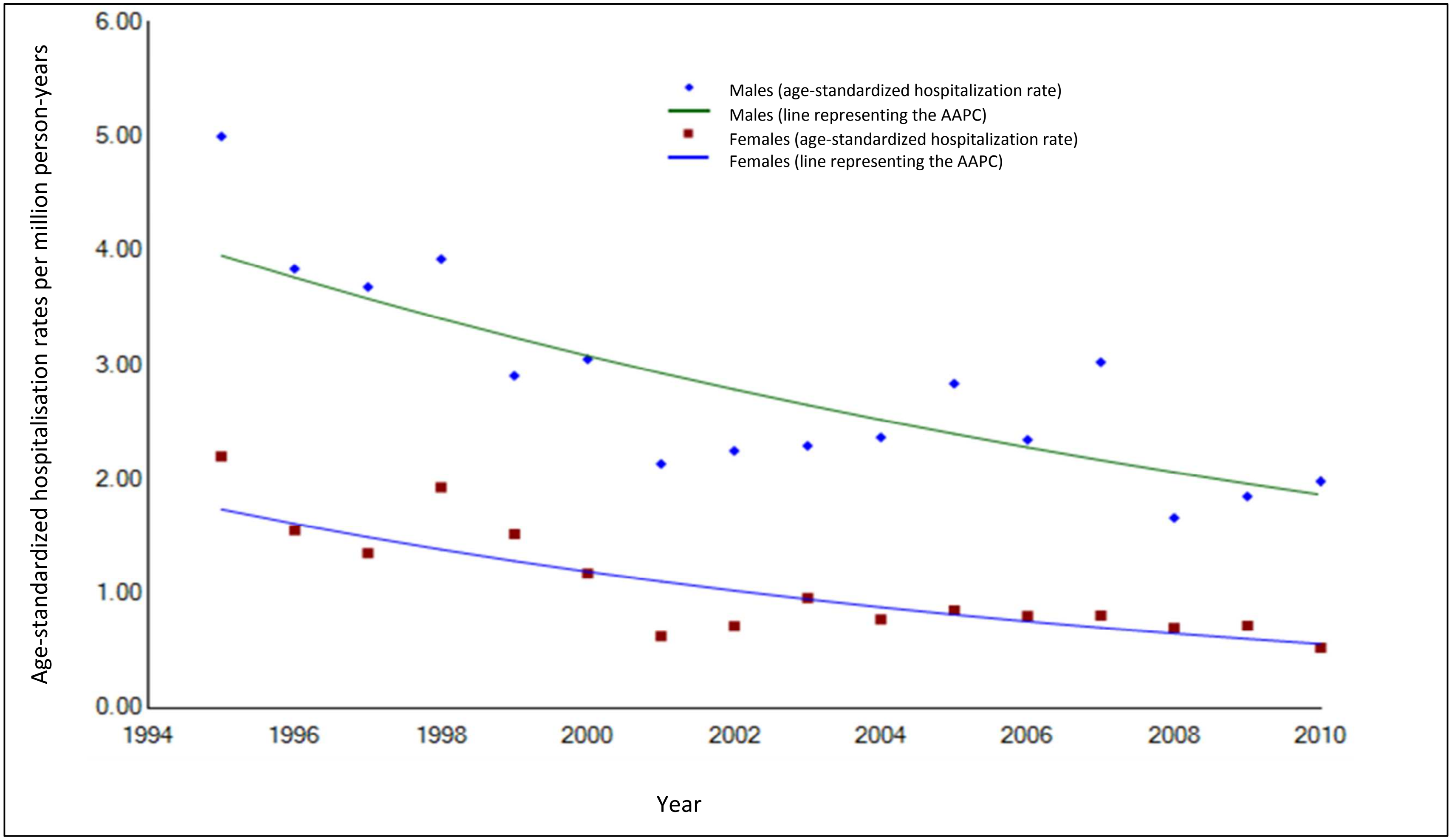
Figure 1. Age-standardized non-intentional non-fire related CO poisoning mortality trends in Canada, by sex (1981 – 2009).



Squares and diamonds are age-standardized mortality rates.
Average annual percent change (AAPC) males = -3.75 (-4.68 – -2.82)
Average annual percent change (AAPC) females = -6.21 (-12.57 – 0.73)

Figure 2. Age-standardized non-intentional non-fire related CO hospitalization rates in Canada, by sex (1995 – 2010).



Squares and diamonds are age-standardized hospitalization rates.
Average annual percent change (AAPC) males = -4.89 (-6.62 – -3.13)
Average annual percent change (AAPC) females = -7.29 (-9.40 – -5.12)

Figure 3. Non-intentional non-fire related CO poisoning mortality (1981 – 2009) and hospitalization (1995 – 2010) rates, by year, Canada.

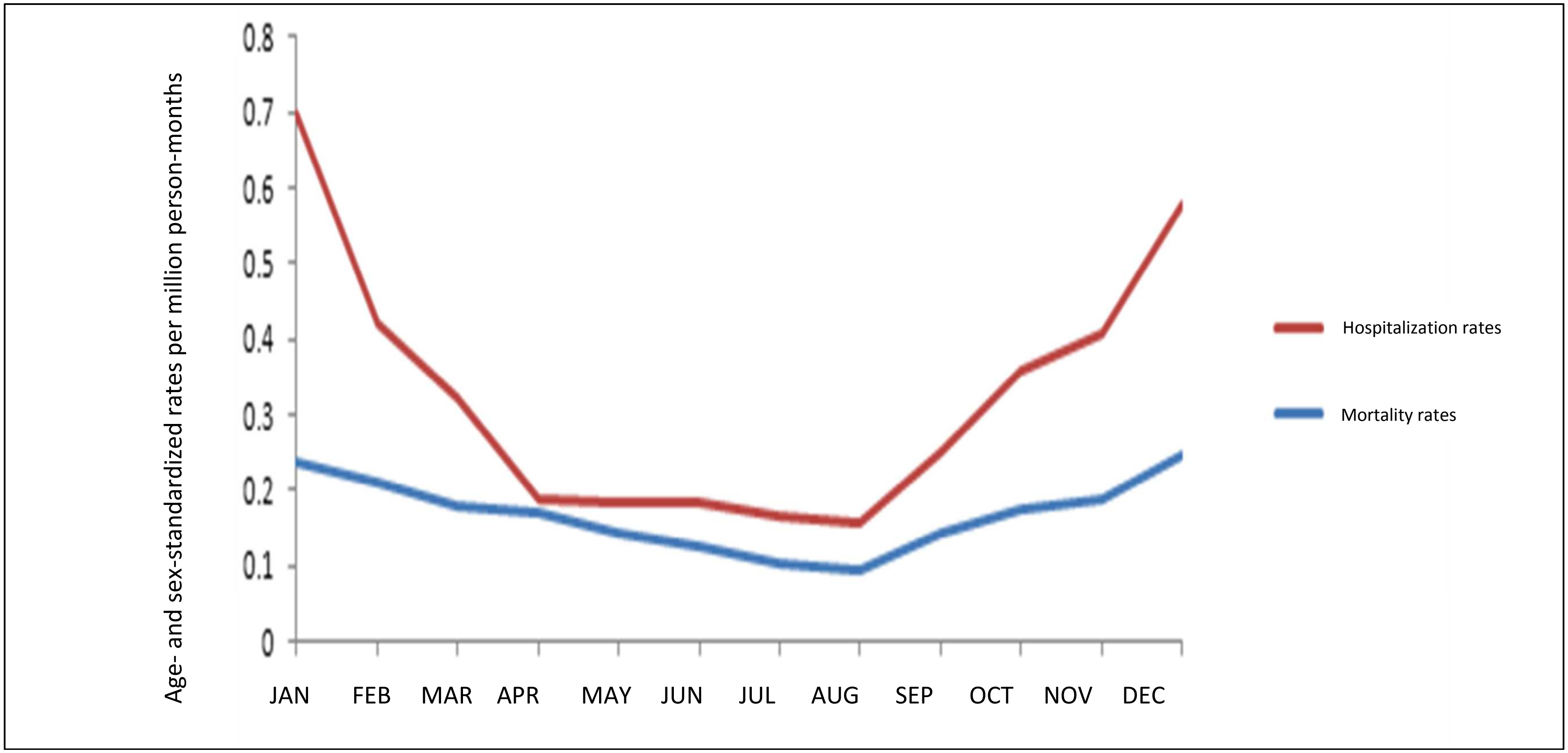


Table 1. Trends of age- and sex- standardized non-intentional non-fire related CO poisoning mortality and hospitalization rates, by Canadian province and overall for Canada.

	Mortality					Hospitalization				
	Rate[1]		Total study period (1981 – 2009)			Rate[1]		Total study period (1995 – 2010)		
	1981	2009	Number of events	Average annual rate[1]	AAPC[2] (95% CI)	1995	2010	Number of events	Average annual rate[1]	AAPC[2] (95% CI)
Canada	3.58	1.24	1,808	2.18	**-3.46 (-4.59 – -2.31)**	7.07	2.57	1,984	3.85	**-5.83 (-7.79 – -3.83)**
Alberta	6.77	1.48	254	3.37	**-10.23 (-18.01 – -1.73)**	14.53	4.23	328	6.68	**-8.86 (-11.42 – -6.27)**
British Columbia	2.07	0.00	195	1.99	**-6.04 (-11.93 – -0.20)**	7.25	4.72	365	5.39	0.16 (-5.37 – 6.14)
Manitoba	8.14	0.00	112	3.48	**-15.14 (-26.57 - -1.92)**	9.19	0.63	70	3.82	-11.13 (-30.91 – 14.26)
New-Brunswick	3.90	6.32	72	3.27	-12.19 (-26.21 – 4.52)	9.07	2.21	76	6.00	**-23.76 (-39.19 – -4.44)**
Newfoundland and Labrador	4.63	0.00	34	2.11	-9.97 (-25.58 – 8.94)	16.14	6.49	55	6.33	1.08 (-7.21 – 10.12)
Nova Scotia	0.00	10.41	56	2.12	-10.32 (-25.11 – 7.3)	5.18	1.63	25	1.55	-27.58 (-18.00 – 98.52)
Ontario	3.12	0.37	519	1.71	**-5.44 (-7.31 – -3.54)**	4.47	1.82	500	2.51	**-5.72 (-8.42 – -3.04)**
Quebec	2.87	2.30	407	1.93	-5.51 (-11.30 – 0.71)	6.96	1.32	392	3.22	**-8.68 (-13.28 – -3.91)**
Saskatchewan	7.54	0.00	128	4.47	**-29.48 (-37.38 – -20.61)**	5.76	7.98	145	8.89	-3.90 (-9.36 – 1.91)

1. Rates are reported per million population
2. AAPC: Average annual percent change in rates

† Statistically significant results are in **bold font**

£ The province of Prince Edward Island, the Northwest Territory, the Nunavut Territory and the Yukon Territory were excluded for the stratified analyses due to small number of cases.

Table 2. Non-intentional non-fire related CO poisoning mortality and hospitalization rates, by age and sex, Canada.

Age and sex categories	Mortality					Hospitalization				
	Rate[1]		Overall study period (1981 – 1999)			Rate[1]		Overall study period (1995 – 2010)		
	1981	1999	Number of events	Average annual rate[1]	AAPC[2] (95% CI)	1995	2010	Number of events	Average annual rate[1]	AAPC[2] (95% CI)
Females										
≤ 14	0.04	0.03	9	0.02	-8.13 (-22.20 – 8.47)	0.38	0.11	77	0.17	-11.26 (-26.01 – 6.52)
15 - 24	0.18	0.03	47	0.08	-22.63 (-32.64 – -11.21)	0.29	0.09	69	0.15	**-20.21 (-30.79 – -8.01)**
25 - 34	0.04	0.04	21	0.04	**-24.48 (-33.11 – -14.82)**	0.41	0.08	73	0.18	**-8.68 (-14.01 – -3.02)**
35 - 44	0.05	0.12	31	0.06	-12.17 (-23.20 – 0.53)	0.36	0.03	86	0.17	**-8.51 (-13.69 – -3.12)**
45 - 54	0.04	0.03	26	0.05	-7.25 (-21.66 – 9.78)	0.26	0.08	73	0.11	-8.29 (-20.17 – 5.11)
55 - 64	0.04	0.06	23	0.04	-5.57 (-19.91 – 11.16)	0.17	0.08	53	0.09	**-5.73 (-11.01 – -0.09)**
65 - 74	0.05	0.03	29	0.06	5.30 (-11.69 – 25.56)	0.17	0.11	44	0.09	-9.61 (-23.13 – 6.2)
≥ 75	0.10	0.03	23	0.05	**-18.23 (-28.77 – -6.01)**	0.16	0.06	68	0.11	0.26 (-5.92 – 6.80)
Males										
≤ 14	0.07	0.03	23	0.04	-10.32 (-25.61 – 8.13)	0.62	0.26	133	0.29	**-5.31 (-9.18 – -1.30)**
15 - 24	0.62	0.03	157	0.27	**-12.72 (-16.11 – -9.22)**	0.89	0.09	150	0.32	**-9.44 (-15.39 – -3.00)**
25 - 34	0.71	0.16	198	0.40	**-9.31 (-12.48 – -6.01)**	0.60	0.69	204	0.51	-2.52 (-6.37 – 1.59)
35 - 44	0.46	0.42	205	0.41	-0.88 (-5.02 – 3.40)	0.85	0.27	265	0.52	**-6.66 (-9.11 – -4.23)**
45 - 54	0.43	0.31	173	0.32	-1.80 (-3.91 – 0.37)	0.92	0.28	257	0.39	**-4.83 (-7.48 – -2.09)**
55 - 64	0.29	0.09	137	0.26	**-4.88 (-8.11 – -1.49)**	0.55	0.18	221	0.38	**-5.74 (-8.87 – -2.40)**
65 - 74	0.23	0.09	91	0.18	-2.64 (-7.27 – 2.19)	0.16	0.20	130	0.24	-2.09 (-7.20 – 3.41)
≥ 75	0.15	0.17	70	0.14	-1.36 (-12.01 – 10.63)	0.32	0.08	81	0.13	-2.89 (-7.79 – 2.32)

1. Rates are reported per million population
2. AAPC: Average annual percent change

† Statistically significant results are in **bold font**

Table 3. Age- and sex- standardized non-intentional non-fire related CO poisoning mortality and hospitalization rates, by place of occurrence of CO exposure, Canada.

Place of occurence	Mortality					Hospitalization				
	Rate[1]		Total study period (1981 – 2009)			Rate[1]		Total study period (1995 – 2010)		
	1981	2009	Number of events	Average annual rate[1]	AAPC[2] (95% CI)	1995	2010	Number of events	Average annual rate[1]	AAPC[2] (95% CI)
Home/residential	1.94	0.66	930	1.17	**-5.09 (-6.46 – -3.68)**	2.65	1.59	942	1.82	-2.51 (-5.32 – 0.34)
Occupational	0.27	0.08	117	0.15	**-6.48 (-10.37 – -2.39)**	1.22	0.17	264	0.52	**-6.41 (-10.73 – -1.92)**
Recreation/sports	0.03	0.00	23	0.03	**-13.07 (-19.38 – -6.29)**	0.10	0.03	19	0.04	**-23.05 (-35.51 – -8.23)**
Public	0.50	0.06	105	0.13	**-10.10 (-17.01 – -2.60)**	0.17	0.08	54	0.11	**-12.97 (-23.88 – -0.48)**
Other/unknown	0.36	0.14	633	0.21	-3.80 (-8.48 – 1.23)	1.33	0.66	705	0.82	-2.52 (-6.01 – 1.10)

1. Rates are reported per million population
2. AAPC: Average annual percent change

† Statistically significant results are in **bold font**

Table 4. Incidence rate ratios (IRRs)[1] for selected determinants of CO poisoning mortality (1981-1999) and hospitalization (1995-2010) in Canada.

Selected determinants	Mortality		Hospitalization	
	IRR	95% CI	IRR	95% CI
Females				
≤ 14	**0.36**	**0.17 – 0.79**	0.83	0.60 – 1.14
15 - 24	**2.46**	**1.48 – 4.14**	1.02	0.73 – 1.42
25 - 34	1.00	-	1.00	-
35 - 44	**1.75**	**1.07 – 3.06**	1.04	0.76 – 1.42
45 - 54	**1.93**	**1.08 – 3.49**	1.00	0.73 – 1.39
55 - 64	**2.10**	**1.16 – 3.78**	1.04	0.73 – 1.49
65 - 74	**3.35**	**1.92 – 5.87**	1.15	0.79 – 1.68
≥ 75	**3.56**	**1.97 – 6.42**	**1.90**	**1.36 – 2.64**
Males				
≤ 14	**0.10**	**0.06 – 0.15**	**0.50**	**0.40 – 0.62**
15 - 24	0.86	0.70 – 1.06	**0.76**	**0.62 – 0.94**
25 - 34	1.00	-	1.00	-
35 - 44	1.19	0.98 – 1.45	1.16	0.97 – 1.38
45 - 54	**1.38**	**1.12 – 1.68**	**1.27**	**1.06 – 1.54**
55 - 64	**1.42**	**1.13 – 1.75**	**1.60**	**1.32 – 1.93**
65 - 74	**1.35**	**1.05 – 1.73**	**1.39**	**1.12 – 1.73**
≥ 75	**1.88**	**1.43 – 2.48**	**1.32**	**1.00 – 1.68**
Sex				
Females	1.00	-	1.00	-
Males	**5.31**	**4.57 – 6.17**	**2.77**	**2.51 – 3.03**
Month				
January	**2.23**	**1.67 – 2.97**	**4.48**	**3.56 – 5.70**
February	**2.14**	**1.60 – 2.86**	**2.71**	**2.10 – 3.52**
March	**1.49**	**1.08 – 2.03**	**2.08**	**1.58 – 2.72**
April	**1.51**	**1.09 – 2.05**	1.22	0.90 – 1.63
May	1.38	1.00 – 1.90	1.17	0.87 – 1.58
June	1.22	0.89 – 1.70	1.19	0.88 – 1.60
July	1.07	0.77 – 1.51	1.06	0.78 – 1.44
August	1.00	-	1.00	-
September	1.35	0.98 – 1.86	**1.60**	**1.21 – 2.14**
October	**1.75**	**1.30 – 2.39**	**2.27**	**1.75 – 2.97**
November	**1.67**	**1.23 – 2.27**	**2.59**	**2.01 – 3.39**
December	**2.18**	**1.65 – 2.94**	**3.71**	**2.89 – 4.76**

1. Incidence rate ratios were mutually adjusted for age group, gender, month of occurrence and year of occurrence.

† Statistically significant results are in **bold font**