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The air quality health index and emergency department visits for injury

Abstract

Introduction. The purpose of this study was to investigate the associations of ambient air quality with emergency department (ED) visits for injury.

Aim. To explore correlations between ED visits for injury and ambient air pollution.

Materials and methods. Considered health outcomes are ED visits for injury (ICD-9 codes: 800-999) in Edmonton, Canada, for the period from April 1998 to March 2002 (1,444 days). Air pollution concentration in the ambient air is represented as a daily maximum of the Air Quality Health Index (AQHI). The AQHI value encapsulates levels of three urban ambient air pollutants (ozone, nitrogen dioxide and fine particulate matter), weighted by constant risk coefficients. A time-stratified case-crossover design, using conditional logistic regression and conditional Poisson regression, was realized to assess the associations. The risk, reported as odds ratio and relative risk, was estimated using log-linear models and parametric non-linear concentration-response functions.

Results. The strongest effects were observed for young male patients in the cold season (October-March). Lagged exposures were found to have positive statistically significant associations.

Discussion. The study results indicate that air quality was associated with increased risk of daily ED visits for injury. This study determined concentration-response functions which allow one to assess the effects for various levels of the AQHI.

Keywords: ambient air pollution, concentration, exposure, index, nonlinear.

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INTRODUCTION

Human health may be affected by a variety of environmental factors and among them is ambient air pollution. Every human organ can be impacted by the polluted air. Though the modes of entrance of air pollutants into the human body are limited, the resultant physiological response can present in a wide spectrum of health problems. Air pollution exposure may trigger unexpected and often unpredictable health conditions [1-6]. For many years environmental epidemiology considered only a naive interpretation of this phenomenon. The studies were limited and focused mainly on the respiratory health conditions. Such scenario assumed the following direct relation: a human inhales air containing pollutants and the air pollutants only affect respiratory system. For example, using this out-dated interpretation, it was assumed that air pollutants do not affect cardiac health. Currently, there is a much wider variety of health conditions considered to be related to air pollution, though the full range of health problems has yet to be fully-established [6]. Also, for many health problems, the biological mechanism of the air pollution related health impacts are not yet well known. Progress in statistical techniques connected to environmental epidemiology allows easier and faster to asses many health conditions in relation to air pollution. Examples of previous research on various manifestations of environmental exposure reactions include investigations on headaches, migraines, depression, drug abuse, suicide, skin, sense organs and other health conditions and problems [4,6-8]. The recently developed statistical methods are fast, reliable, easy to implement and use, allowing for verification of many hypotheses on the associations of health and ambient air pollution concentration levels.

An injury, damage to the human body caused by external energies, is usually the result of a sudden impact of energy such as mechanical, gravitational, electrical, thermal, chemical, hydraulic, pneumatic, nuclear, radiation or other energy that can harm human health. The acute absence of oxygen may also result in injury or death [9]. Damage to human health can be physical or due to emotional trauma.

In this work, we considered emergency department (ED) visits for injury in relation to exposure to ambient air pollution measured by air quality index. All cases of ED visits for injury are summarized and their daily counts are considered as one health problem. In general, injuries due to vehicles, burns, falling, drowning, poisoning and others are predominantly the results of poor attention capacity, weakness and fatigue, stress, excitation and poor cognitive judgment of the situation [9]. Though the majority of the injuries was unintentional, a minority of ED visits for injury may have been intentional or self-harming. It is also possible that some of ED visits for

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injury are also a result of mental health conditions, probably suicide attempts among them, with an intention of self-harm to result in death.

AIM

The hypothesis in this work is that exposure to ambient air pollution is associated with an elevated risk of ED visits for injury. The air pollution concentration levels are represented by values of the index, which is based on three ambient air pollutants (fine particulate matter, ozone, and nitrogen dioxide). Using statistical techniques, though causality cannot be proved, the pattern of the correlations can be established. Not all ED visits are triggered by varying levels of the air pollution concentrations. This study estimated some positive statistically significant associations of ED visits with ambient air quality value.

MATERIAL AND METHODS

In this work as health data ED visits for injury in Edmonton, Canada were studied. The database used contains records of diagnosed ED visits from five hospitals in Edmonton for the period from April 1992 to March 2002 (consisting of almost three million separate records). The cases related to this study were identified and retrieved using the International Classification of Diseases Ninth Revision (ICD-9) with the corresponding codes: 800-999. Time resolution in this study is day and by a consequence daily individual health events or daily summarized counts were analyzed.

The Air Quality Health Index (AQHI) daily maximum values are used to represent the concentration levels of three ambient air pollutants. The considered maximum value well represents acute changes in air pollution concentrations. The AQHI is developed in Canada as a health protection tool [10]. It is used to advise individuals to potentially adjust their outdoor activities during increased levels of ambient air pollution. The AQHI value is represented on the scale from 1 to 10, and 10+. Larger value indicates larger risk. The calculation of the AQHI values uses rolling 3-hour average air pollutant concentrations – the average of the current and 2 previous hours. The AQHI value is determined according to the following formula:

$$AQHI = \frac{1000}{10.4} * [\exp(0.000537 * O_3) + \exp(0.000871 * NO_2) + \exp(0.000487 * PM_{2.5}) - 3],$$

where O_3 (ground level ozone, in ppb), NO_2 (nitrogen dioxide, in ppb), and $PM_{2.5}$ (fine particulate matter, in g/m^3) are entered as 3-hour moving averaged concentrations. The used (fixed) coefficients are based on the excess mortality risk estimated for large cities in Canada.

The measurements for fine particulate matter in Edmonton have been available since April 18, 1989. This restricted the current study period to 1,444 days (April 18, 1998 – March 31, 2002).

In the statistical models, covariates, daily average of temperature and relative humidity are represented in the form of natural splines with three degrees of freedom [11,12]. In the models all variates were lagged by the same number of days.

This work is a short-term air pollution exposure study analyzing the associations of air pollution and health conditions. A case-crossover design is applied with a time-stratified approach to define the control periods [13,14]. Conditional logistic regression was realized to fit the statistical models to estimate odds ratios. The analysis was done for a series of age groups, by sex and by season (warm: April-September; cold: October-March). Conditional Poisson regression models were also used as a flexible alternative technique to the case-crossover methodology [15-17]. Based on this approach, the parametric concentration-response functions were estimated for the exposure with various lags, for males and females [18].

To investigate the concentration-response associations, the transformation of the concentration levels was realized. Here the logarithmic function, multiplied by the logistic weighting function, was applied. Representing the concentration levels by the variable z (here z=AQHI), the following formula was used to estimate relative risk (RR) as a function of the variable z, RR(z)=exp(β(z)). The formula to determine the value of β(z) is as follows:

$$\beta(z) = \beta * \frac{\log(z)}{1+\exp\left(\frac{\mu - z}{r * \tau}\right)},$$

where r is the range of the concentrations, and μ (mu) and τ (tau) are the parameters of the logistic function. For given values of the parameters mu and tau, the coefficient β (Beta) was estimated from the applied regression model. The Akaike Information Criterion (AIC) value was used to assess the goodness of fit and this criterion allows for the adjustment of the values of the parameters mu and tau. This process is done iteratively, with a goal to minimize the AIC value. Finally, the value of Beta and its standard error, mu and tau are determined for best fit according to assumed criterion (AIC) [18].

RESULTS

During the period from April 18, 1989 to March 31, 2002 (1,444 days) 372,510 diagnosed ED visits for injury were retrieved. Among these patient visits, 223,867 (60%) were for male and 148,643(40%) were for female. The frequency of ED visits by age (in years) for male and female patients, shows two peaks, one around 20 and another around 40 years of age. Up to approximately 55 years of age, ED visits for injury are higher for males than for females. In the five participating hospitals, the summarized and reported lowest daily number of ED visits was 65, with the highest of 367. February had the lowest frequency of visits for injury (7.2%) and August had the highest (9.5%). The highest frequency, by day of week, was 15.6% on Saturdays and the lowest was 13.5% on Tuesdays.

For male patients, the most frequent ED visits were the following: 20,530 (ICD-9: 873; Other open wound of head), 14,367 (ICD-9: 883; Open wound of finger(s)), 10,915 (ICD-9: 847; Sprains and strains of other and unspecified parts of back) and 10,530 ED visits with (ICD-9: 845; Sprains and strains of ankle and foot). For female patients, the most frequent ED visits were 10,651 (ICD-9: 847; Sprains and strains of other and unspecified parts of back) and 10,163 (ICD-9: 845; Sprains and strains of ankle and foot).

Two large groups of poisoning and toxicity effects belong to the considered health outcomes: "Poisoning by drugs, medicinal and biological substances" – (ICD-9 codes: 960-979) and "Toxic effects of substances chiefly nonmedicinal as to source" – (ICD-9 codes: 980-989). In the first group were identified 11,634 ED visits with 4.943 (42%) visits for males and 6,751 (58%) visits for females. There is no information on the character of using these substances, intentional or non-intentional [4]. In the group identified by the ICD-9 codes: 980-989 were obtained 4,840 cases with 2,922 (60%) for males and 1,918 (40%) for females.

TABLE 1. The statistics of the variables used in the study. Edmonton, Canada. April 1989 – March 2002.

Factor:	AQHI	TEMP	RHUM	AQHI-W	TEMP-W	RHUM-W	AQHI-C	TEMP-C	RHUM-C
Min.	1.5	-24.5	25.1	1.5	-22.5	25.1	1.6	-24.5	33.8
1st Qu.	3.4	-3.1	54.5	3.4	7.6	50.0	3.6	-10.2	60.0
Median	4.2	5.9	63.6	4.1	12.9	59.9	4.3	-3.1	68.0
Mean	4.3	4.6	63.4	4.3	11.1	59.9	4.4	-4.3	68.2
3rd Qu.	5.0	14.1	72.8	5.0	17.0	69.3	5.1	1.6	76.7
Max.	10.5	26.5	98.0	10.5	26.5	98.0	9.8	14.0	96.6

Note: AQHI – Air Quality Health Index, daily maximum value, TEMP – temperature (°C), RHUM – relative humidity (%), W – warm period (April – September), C – cold period (October – March), Min – minimum, Max – maximum, Qu. – quartile.

TABLE 1. represents the environmental variables statistics: daily maximum and minimum of the AQHI values, temperature, and relative humidity for warm, cold, and season data combined. Figure 1. presents the estimated odds ratio (OR) and 95% confidence interval (CI), for 67 age groups, for an increase in the AQHI daily maximum value (lagged by 1 day) by one unit increase. The solid lines are used to emphasise the trends. The age groups studied are defined by the following series of age intervals [A, A+19], where A=0,1,…,66. Thus one point on the x-axis represents one age group with the specified value of A. For example, for the point A=1, the corresponding age group is 1-20. The last considered age group is 66-85. The upper panel of Figure 1 illustrates the results for male patients and the lower panel illustrates the results for female patients. Young males and females show positive associations and they are large for males. For females also positive and statistical significant associations are noted for four age groups (A = 36, 37, 38, and 39).

Figure 2., similar to Figure 1., illustrates the estimated ORs of the two seasonal periods, warm (April-September) and cold (October-March) for the same 67 age groups as defined in Figure 1. Stronger associations are observed for the cold period than in warm months. The results presented in Figures 1 and 2 were obtained by using the case-crossover method and conditional logistic regression to realize the models. For each age group the corresponding OR is estimated using log-linear model.

Figures 3. and 4. show the estimated relative risk (RR) for the considered concentration levels of exposure, here expressed as daily maximum of the AQHI values. Figures 3. and 4. were generated using the case-crossover design realized in the form of conditional Poisson regression. The obtained shapes represent the concentration-response relationship, i.e. the values of RR for the concentrations. Figure 3. illustrates the concentration-response for male patients for the exposure with lag 0, 1, 2 and 3. Figure 4. shows similar results for female patients, with lag 1, 2, 3, and 4. Female ED visits for lag 0 (same day) were negative (data not shown). The estimated RRs are shown as solid lines and the corresponding the 95% CIs are represented by dotted lines.

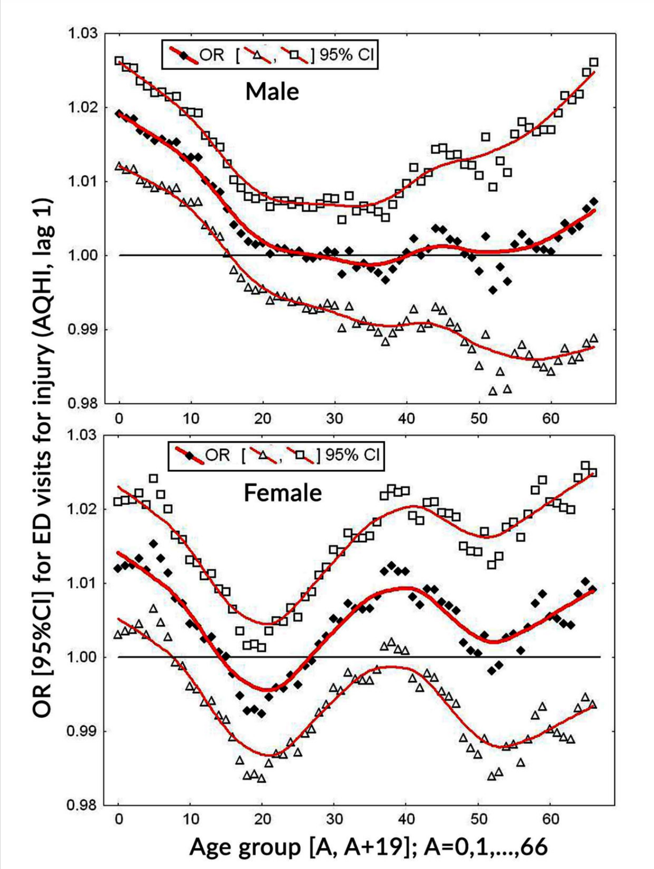

FIGURE 1. The estimated OR [95%CI] for 67 age groups [A, A+19]. ED visits males (upper panel) and –females (lower panel). Edmonton, Canada, 1998-2002.

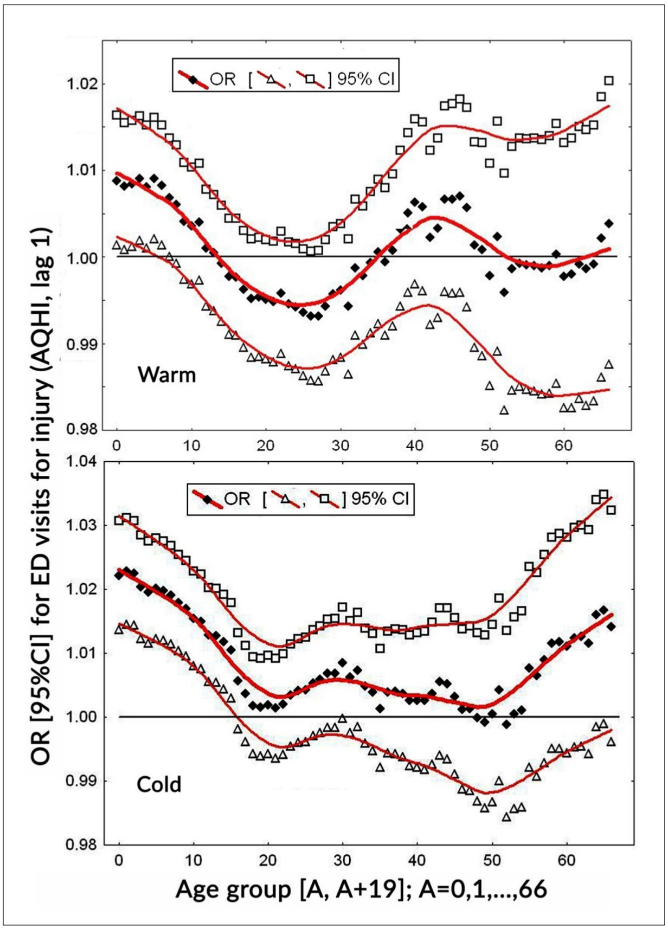

FIGURE 2. The estimated ORs [95%CI] for 67 age groups [A, A+19]. ED visits warm period (April-September; upper panel) and cold period (October-March; lower panel). Edmonton, Canada, 1998-2002.

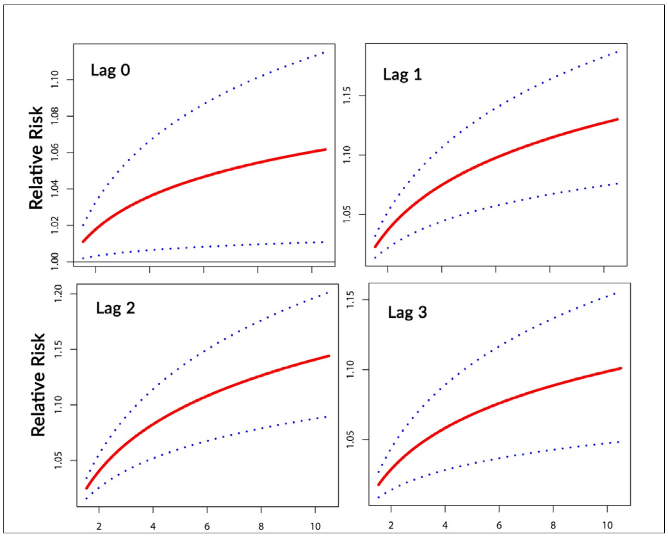

FIGURE 3. The estimated concentration-response shapes of RR for male patients (Lag = 0, 1, 2, and 3 days). Edmonton, Canada, 1998-2002.

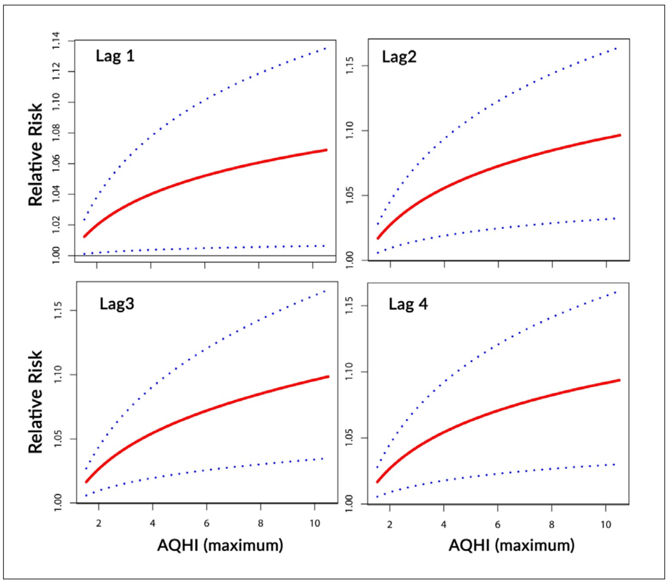

FIGURE 4. The estimated concentration-response shapes of RR for male patients (Lag = 0, 1, 2, and 3 days). Edmonton, Canada, 1998-2002.

DISCUSSION

Applying a time-stratified case-crossover technique to 372,510 ED visits, this study found that the odds ratio and relative risk of ED visits for injury are positively associated with exposure measured by using the AQHI values. The AQHI values are based on three air pollutants: ground level ozone, nitrogen dioxide and fine particulate matter. These air pollutants (analyzed separately), and other air pollutants used individually in the case-crossover models, show significant associations with injury: ambient ozone for lag 0, fine particulate matter for exposure lagged by 1, 2, 3, and 5 days, and nitrogen dioxide for lag 1 to 6 days. It is interesting to observe that carbon monoxide and sulphur dioxide also show positive associations with injury for lagged exposure from 1 to 6 days, and up to 7 days in the case of carbon monoxide. The presented study confirms findings on the association of ambient air pollution exposure and injury.

This study hypothesized that the AQHI values appropriately represented air pollution concentrations and index values are associated with the number of ED visits for injury. The presented results support this hypothesis. There are a few other studies which use the AQHI value as representatives of environmental exposure [6, 19-24].

Several epidemiologic studies have reported the associations of air pollution exposure with neurological and behavioral effects, such as poor cognitive judgments, depression, drug abuse, unethical behaviours, personal disorders, suicide and others [1-5,8,9]. Air pollution could induce neurodegenerative disease by generating an inflammatory stimulus to the central nervous system [25,26].

Main limitation in this work is the assumption that the considered exposure is the same for all individuals across the city of Edmonton. Other weather factors, as rain, snow, frost or others, may affect the considered health outcomes. While there is the possibility of unknown confounders, the case-crossover design should help mitigate this. Primary diagnosis of ED visit, injury, is probably well classified and coded by a nosologist. The size of the considered population study is large and it allows to be more confident on the statistical techniques.

CONCLUSION

The results from this work indicate consistence associations between ambient air quality values and risk of daily ED visits for injury. This area of the study of public health problems still not yet well established [27-29].

DATA AVAILABILITY STATEMENT
The data are available upon reasonable request.

CONFLICT OF INTEREST
None declared.

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