Should People Be Physically Active Outdoors on Smog Alert Days?

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ABSTRACT

Background: Given the importance of physical activity to well-being, there is a need to encourage people to be physically active year-round. At the same time, many people are vulnerable to adverse health effects from air pollution, especially on smog alert days. This study was undertaken to determine when air pollution levels tend to be lowest so that the public can modify strenuous outdoor activity accordingly.

Methods: Existing hourly air pollution data for Toronto were analyzed to determine how pollutant levels varied from hour to hour throughout each 24-hour day, to identify the times when pollution levels are at their lowest on average.

Results: Pollutant levels vary throughout the day, with concentrations of some pollutants (such as ozone, particles and sulphur dioxide) being highest during mid-day, and others (such as carbon monoxide and nitrogen dioxide) being highest with morning rush hour. Overall, pollutant concentrations tend to be lowest before seven a.m. and after eight p.m.

Interpretation: The public should be encouraged to maintain regular physical activity outdoors while monitoring any air pollution-related symptoms. The intensity of outdoor activity should be reduced, or activities replaced with indoor exercise, at those Air Quality Index (AQI) levels that trigger individual symptoms and when AQI values exceed 50. Where possible, strenuous activity should be taken when and where air pollution levels tend to be lowest, namely early in the morning and in low-traffic areas. More research is required to guide development of health protective advice on exercising when air quality is poor.

MeSH terms: Exercise; air pollution; smog; health promotion; motor activity

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

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Over the last decade, evidence has accumulated confirming that air pollution, even at the levels experienced in urban centres in North America, continues to pose a significant health risk.[1-4] Effects are wide ranging, and include reduced lung function, acute and chronic bronchitis, asthma attacks, strokes, high blood pressure and an elevated risk of congenital heart defects.[5] Studies identify asthmatics, diabetics and those with congestive heart failure as being at particularly elevated risk from air pollution.[5] Using data from 1999, Toronto Public Health estimated that air pollution associated with acute exposures to ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2), as well as the health risk associated with chronic exposure to respirable particulate matter ($PM_{2.5}$), contributed to about 1,700 premature deaths and 6,000 hospitalizations in Toronto on an annual basis.[6]

While actions to improve air quality continue to be taken, progress is slow. For example, trend data for key air pollutants in Toronto reveal little improvement in air quality over the last two decades.[7] The Ontario Ministry of the Environment (MOE) issues a "smog advisory", also known as a smog alert, when an Air Quality Index (AQI) value of 50 or greater is expected to be widespread and persistent. Air quality is described as "poor" at an AQI of 50 or greater. In 2002, the Ministry included $PM_{2.5}$ in the AQI, which is likely to result in more days where the AQI reading will be in the poor category and thus will trigger a "smog alert". As well, climate change and its associated increase in hot days is likely to increase the number of days with poor air quality in Ontario.

Regular physical activity has a profound and positive influence on the health of people at all stages of their lives, yet only one third of people living in Toronto are sufficiently active for good health.[8] The absence of regular physical activity is associated with increased risk of cardiovascular disease, diabetes, osteoporosis, obesity and mental health problems.[9-12] At the same time, numerous studies have shown that adverse health impacts increase with increased activity levels in the presence of air pollutants, and that exposure to air pollutants during exercise adversely impacts lung function and athletic performance.[13-16]

With each smog alert, health officials reiterate precautionary messages to reduce vigorous physical activity outdoors to minimize the intake of air pollutants. This presents a dilemma. While regular physical activity has an important, positive influence on the health of people, poor air quality can act as a barrier to increased physical activity and negatively affect the health of those who exercise outdoors.

Studies have shown that concentrations of CO and NO_2 are much lower in low-traffic areas (e.g., residential) than in high-traffic areas.[17,18] Many pollutants (particles, SO_2, O_3, metals and benzene) are generally lower inside homes than outside.[19-24] Compared with outside, other air pollutants – including CO, some aromatic hydrocarbons and many volatile organic compounds (e.g., toluene, xylenes, formaldehyde and chlorinated methanes) – tend to be higher indoors.[22,24-27] However, more research is required on the health significance of this. Studies also indicate that levels of some pollutants may be lower in homes with air conditioning than in homes without.[28,29]

Given that many pollutants (such as O_3 and $PM_{2.5}$) show no evidence of a threshold concentration below which there is no adverse effect,[1] even healthy people may wish to plan vigorous exercise (such as jogging and running) for times of the day when air pollution levels are lowest. A review of available air quality data was undertaken to determine when overall air pollution levels tend to be lowest in Toronto. This review enables health officials to refine their guidance on ways to minimize exposure to air pollutants when members of the public engage in physical activity outdoors.

TABLE I

Seasonal Variation in Daily Mean Pollutant Levels (Toronto 1997-2000)

Pollutant	Units	Winter (Dec, Jan, Feb) mean (s.d.)*	Summer (Jun, Jul, Aug) mean (s.d.)	t-test significance level
SO_2	ppb	5.5 (0.5)	4.2 (0.7)	<0.0001
O_3	ppb	12.3 (3.0)	27.9 (11.6)	<0.0001
NO_2	ppb	28.4 (3.0)	24.3 (4.5)	<0.0001
CO	ppm	1.2 (0.1)	1.1 (0.1)	>0.5
$PM_{2.5}$	µg/m^3	8.4 (0.9)	13.4 (0.8)	<0.0001
PM_{10}	µg/m^3	18.8 (3.9)	23.1 (2.1)	<0.0001

* s.d. – standard deviation

TABLE II

Mean Pollutant Levels When AQI 50 versus <50 (Toronto 1997-2000)

Pollutant	Units	AQI 50 mean (s.d.)*	AQI <50 Mean (s.d.)	t-test significance level
SO_2	ppb	7.0 (1.8)	4.7 (0.5)	<0.0001
O_3	ppb	40.5 (19.1)	18.6 (6.0)	<0.0001
NO_2	ppb	32.9 (6.7)	26.1 (3.4)	<0.0001
CO	ppm	1.1 (0.1)	1.2 (0.1)	>0.5
$PM_{2.5}$	µg/m^3	29.0 (2.1)	9.7 (0.8)	<0.0001
PM_{10}	µg/m^3	43.1 (4.7)	19.7 (2.5)	<0.0001

* s.d. – standard deviation

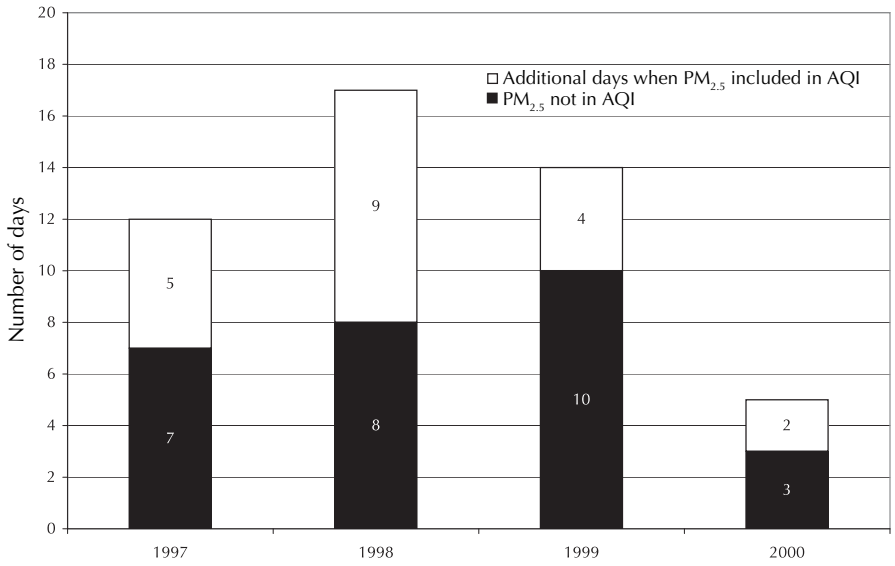

Figure 1. Days of "poor" air quality in Toronto resulting from inclusion of $PM_{2.5}$ in the AQI

METHODS

Existing hourly air pollution data were analyzed to determine how concentrations of O_3, CO, NO_2, inhalable particles (PM_{10}), $PM_{2.5}$, and SO_2 varied from hour to hour throughout each 24-hour day. Pollutant concentrations were obtained from NAPS (National Air Pollution Surveillance) monitoring sites operated by the MOE in Toronto. The monitoring stations were Evans and Arnold (NAPS Station ID 60403), Lawrence and Kennedy (60410), Elmcrest Road (60413) and one station in central Toronto (station location changed slightly during the period: College Street 1974-1981; Breadalbane Street 1981-1990; Bay and Wellesley 1990-2000).

An initial analysis was conducted on all available hourly pollutant levels (SO_2, CO and O_3 data were available 1974-2000; NO_2 1980-2000; PM_{10} 1996-2000; $PM_{2.5}$ 1997-2000). Hourly mean values were calculated for the winter (December to February) and summer (June to August) months. Hourly mean values of all pollutants were also calculated for those days on which the AQI was less than 50, and those on which it was 50 or greater (i.e., days when air quality was "poor"). The "poor" air quality designation was based on one or more pollutants reaching or exceeding the following MOE breakpoint concentrations: NO_2 – 260 ppb; O_3 – 81 ppb; SO_2 – 350 ppb; CO – 31 ppm; and $PM_{2.5}$ – 46 µg/m^3 (based on 3-hour running mean). To reduce variability in hourly means attributable to changes in pollution emissions since 1974, a more focussed analysis was also done using data collected between 1997 and 2000.

TABLE III

Guidance Regarding Physical Activity and Air Pollution *

On Smog Alert Days (When the AQI is 50 or Higher):

- Modify outdoor activities to shift from vigorous activity levels to light activity levels, reduce the duration of activity and introduce more rest breaks. Drink plenty of water before, during and after activity outdoors.
- Consider exercising indoors in a smoke-free environment, and if available, one that is air-conditioned.
- For all people, but especially those with heart or breathing problems (including asthma), monitor any symptoms experienced with different activity levels and as the air quality index (AQI) number increases. Examples of symptoms to watch for include coughing, wheezing, chest tightness, pain with breathing deeply, and difficulty breathing. Anyone experiencing symptoms should reduce their outdoor activity level, and if appropriate, seek medical attention.
- Consider rescheduling events that require continuous vigorous activity to another time when the smog alert is lifted.

On Non-Alert Days (When the AQI is Less than 50):

- If possible, schedule routine vigorous exercise, such as running and jogging, for early in the morning (before 7 a.m.) and in low traffic areas (such as residential neighbourhoods and parks).
- Stay active outdoors but monitor any symptoms experienced with different activity levels and as the air quality index (AQI) number increases. Reduce activity level outdoors when AQI values are above those known to trigger individual symptoms.

* This advice builds on guidance being developed by Health Canada. Examples of activities at different intensities include: **vigorous** – jogging, hockey, basketball; **moderate** – bicycling, brisk walking, raking leaves; **light** – slow pace walking, easy gardening, volleyball.

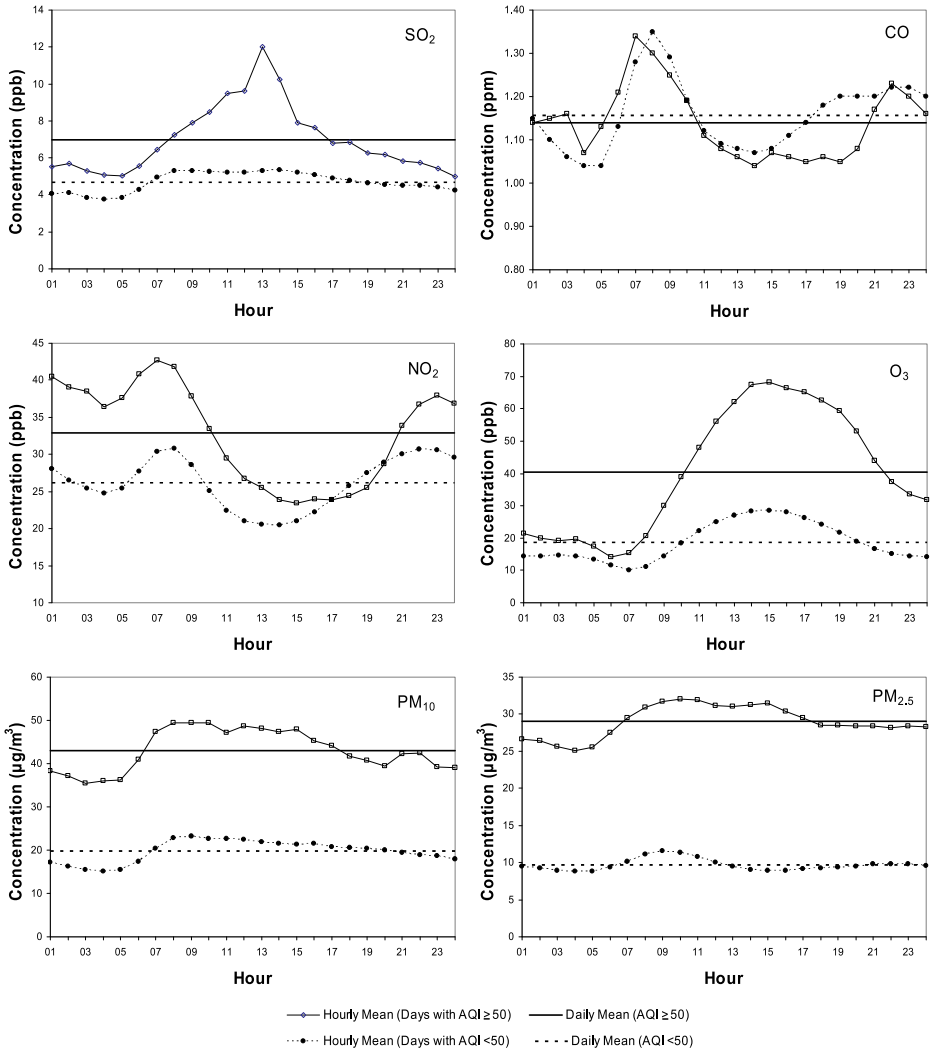

Figure 2. Diurnal fluctuation in hourly pollutant levels (Toronto, 1997-2000)

The SAS *t*-test procedure (SAS Institute Inc., 1999)[30] was used to examine whether daily mean pollutant levels were statistically significant between winter and summer, as well as between smog alert and non-smog alert days. This procedure considers either equal or unequal variances of the two groups but not serial correlation (autocorrelation) within the samples. Since a serial correlation can result in an indication of "significant" differences even when there are no differences, the standard *t*-test was adjusted using Zwiers and von Storch's method[31] to take into account serial correlation in daily air pollution concentrations.

RESULTS

Figure 1 shows the number of days during 1997 through 2000 when the AQI in Toronto was 50 or greater (referred to as "smog alert" days by Toronto Public Health). If the MOE's AQI classification scheme had included $PM_{2.5}$ during the study period, as it does currently, more days would have been categorized as poor air quality ("smog alert") days than were actually recorded at that time. While the largest number of smog alert days would still have occurred in the summer, smog alert days would have been reported from March to December.

The results show that ozone and particle (PM_{10} and $PM_{2.5}$) levels were significantly higher in summer than in winter, while the converse was true for SO_2 and NO_2 levels (Table I). A comparison of mean 24-hour pollutant levels for smog alert days (AQI ≥50) and non-alert days (AQI <50) shows that, with the exception of CO, mean daily pollutant concentrations were significantly higher on smog alert days than on non-alert days at a significance level of <0.0001 (Table II).

The hourly fluctuation in pollutant levels over the recent four-year period (1997-2000) was similar to the pattern seen for the full data set from 1974 to 2000. Each of the five pollutants (SO_2, CO, NO_2, O_3 and particles) had a different diurnal pattern, with particles showing the least diurnal variation (Figure 2). CO and NO_2 showed the closest association with times of "rush hour" traffic, whereas ozone levels peaked during the afternoon and were at their lowest during the morning rush hour. SO_2 peaked just after mid-day.

When comparing levels to the 24-hour daily mean, most pollutants are consistently lowest very early in the morning and late in the evening (Figure 2). This pattern is observed in both summer and winter seasons, and on smog alert and non-alert days. The exceptions are NO_2 and CO, which are at low levels before 6 a.m. and typically peak by 8 a.m., coinciding with morning rush hour. When averaged over many days, there is no pronounced diurnal fluctuation in particle levels, especially for $PM_{2.5}$. PM_{10} and $PM_{2.5}$ levels tend to be especially high all day on poor air quality days.

DISCUSSION

Lack of physical activity is a major public health issue. However, while physical activity promotion is a major priority for public health, officials also need to advise the public about potential adverse impacts of air pollution on health. This is most pronounced during smog events, when the public is reminded to take precautions by staying indoors and limiting strenuous exercise outdoors. Although messages geared at minimizing exposure to pollutants may be important for those who are already physically active, they may inadvertently discourage others who should be more active. People with respiratory and cardiac problems are more sensitive to the impact of air pollution, but at the same time benefit greatly from regular physical activity.

The public looks to its health agencies for guidance (Table III). There is a need to caution everyone, and especially sensitive subpopulations (including seniors and those with asthma, chronic bronchitis, chronic obstructive pulmonary disease and heart problems) to moderate their physical activity outdoors on smog alert days. Most summertime smog advisories in Toronto coincide with the Medical Officer of Health's issuance of a heat warning ("heat alert"). During these high pollution and high heat episodes, it is especially important to modify physical activity levels outdoors. Other precautions recommended during high heat days are to drink plenty of fluids, wear loose-fitting clothing, and take many rest breaks, preferably in the shade or air-conditioned areas, including malls, libraries and public cooling centres set up by municipal agencies during extreme heat events.

It is reasonable to encourage the public to exercise indoors if possible (such as in smoke-free and, if available, air-conditioned environments) on smog alert days, given that levels of many pollutants are generally lower inside homes than outside, and this difference may be even greater on smog alert days. Further research is required, however, to examine the total pollutant burden and health significance of indoor air pollutants compared with those outside, given that some pollutants, such as volatile organic compounds, tend to originate and are much higher indoors.

On non-smog alert days, the public is advised to shift routine personal exercise programs, such as running and jogging, to early morning in low-traffic areas to minimize exposure to air pollutants. Because health impacts occur even on days when the AQI is less than 50 and individuals' sensitivities differ, individuals are advised to calibrate their own sensitivity at different AQI readings, and reduce the intensity of outdoor activity if symptoms occur.

Although some people can adopt ways to minimize exposure to air pollutants, these are not practical for others. For much of the population, it is not easy to undertake physical activity outdoors at times when air pollution levels are lowest. This is especially true for parents with children who must be tended to in the morning, people who cycle to work or school, and for children and adults engaged in daytime sport activities. Given the many health benefits of exercise, healthy adults and children should be encouraged to undertake physical activity outdoors on days when the AQI is below 50, unless future, compelling evidence suggests otherwise.

This study was initiated to identify convenient, daily periods of low air pollution, appropriate for vigorous outdoor physical activity. Instead, the data identified few times when all key pollutants were low. One of the limitations of this study is that the analysis is based on the average air pollution concentrations calculated from four monitoring stations so as to determine overall air pollution conditions in Toronto. While the results provide appropriate guidance for people who move about in the city, it is not known how their exposures to air pollutants compare with those of people who spend most of their time in a specific location or microenvironment.

While there are many barriers to physical activity – limits in physical education opportunities in schools, access to recreational or sports facilities, and availability of green space – it is important to ensure that poor air quality does not become an additional impediment to increased physical activity. Public health agencies have a significant role in promoting air quality improvements, such as through reduced reliance on fossil fuels, increased energy efficiency and a rapid shift to renewable energy sources.

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RÉSUMÉ

Contexte : Étant donné l'importance de l'activité physique pour le bien-être, il faudrait encourager les gens à être actifs à longueur d'année. Cependant, de nombreuses personnes sont vulnérables à la pollution atmosphérique, qui peut avoir des effets indésirables sur la santé, surtout les jours où l'on émet des avis de smog. Notre étude visait à déterminer les moments où les niveaux de pollution atmosphérique ont tendance à être les plus faibles, pour que la population puisse concentrer son activité physique intense à l'extérieur durant ces périodes.

Méthode : Nous avons analysé les données horaires existantes sur la pollution atmosphérique à Toronto pour déterminer les variations horaires des niveaux de polluants pendant chaque période de 24 heures, ce qui nous a permis de cerner les moments où les niveaux de pollution sont les plus faibles en moyenne.

Résultats : Les niveaux de polluants varient au cours de la journée. On détecte les plus fortes concentrations de certains polluants (l'ozone, les particules et l'anhydride sulfureux) vers midi, tandis que d'autres polluants (le monoxyde de carbone et le dioxyde d'azote) sont plus concentrés à l'heure de pointe du matin. Dans l'ensemble, les concentrations de polluants ont tendance à être les plus faibles avant 7 h et après 20 h.

Interprétation : Il faudrait encourager la population à pratiquer régulièrement une activité physique à l'extérieur tout en surveillant les symptômes pouvant être associés à la pollution atmosphérique. Il faudrait réduire l'intensité de l'activité à l'extérieur (ou pratiquer une activité physique à l'intérieur) lorsque l'indice de la qualité de l'air (IQA) atteint un niveau qui déclenche des symptômes chez la personne ou lorsque l'indice est supérieur à 50. Il est préférable de limiter l'activité physique intense aux moments et aux endroits où les niveaux de pollution atmosphérique ont tendance à être faibles, à savoir tôt le matin et dans les zones à faible densité de circulation. Il faudrait pousser la recherche pour orienter l'élaboration de conseils de protection de la santé portant sur l'activité physique lorsque l'air est de mauvaise qualité.