Climate change and the new normal for cardiorespiratory disease

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Climate change is already affecting the cardiorespiratory health of populations around the world, and these impacts are expected to increase. The present overview serves as a primer for respirologists who are concerned about how these profound environmental changes may affect their patients. The authors consider recent peer-reviewed literature with a focus on climate interactions with air pollution. They do not discuss in detail cardiorespiratory health effects for which the potential link to climate change is poorly understood. For example, pneumonia and influenza, which affect >500 million people per year, are not addressed, although clear seasonal variation suggests climate-related effects. Additionally, large global health impacts in low-resource countries, including migration precipitated by environmental change, are omitted. The major cardiorespiratory health impacts addressed are due to heat, air pollution and wildfires, shifts in allergens and infectious diseases along with respiratory impacts from flooding. Personal and societal choices about carbon use and fossil energy infrastructure should be informed by their impacts on health, and respirologists can play an important role in this discussion.

Key Words: Air pollution; Cardiorespiratory disease; Climate change; Floods; Forest fires; Heat effects

The global environment is undergoing profound change due to increases in temperatures and changes in the hydrological cycle (1). Climate change is a serious public health threat, both globally and nationally. In a recent update, the WHO estimated that 250,000 additional deaths per year will be caused by climate change between 2030 and 2050 (2). In addition to increased mortality, millions of disability-affected life-years will be lost annually due to climate change impacts over the previous three decades (3). Although the burden of these effects is disproportionately distributed to low-income countries, the health of the Canadian population is also affected. Although more exhaustive reviews have summarized and described the observed and potential impacts (4), our objective is to provide a brief overview from a Canadian perspective.

A growing body of epidemiological literature specifically associates climate change with changing distributions of cardiorespiratory disease and mortality (1.4-8), which includes both direct and indirect effects. The indirect effects include shifts in allergen load, changes in the distribution of vector-borne illnesses, and societal disruptions that can change risk factors for populations affected by extreme events, sea level rise and forced migration (9-11). The more direct effects include heat-related exacerbations of conditions such as asthma, chronic obstructive pulmonary disease (COPD) and cardiovascular disease (CVD), increases in hazardous air pollution days from ozone and particulate matter, and mortality and morbidity from extreme weather events and their aftermaths (9,10,12). We highlight some specific examples of impacts that should be considered by Canadian respirologists.

AIR POLLUTION (ASTHMA AND COPD)

Increasing atmospheric temperatures and related meteorological effects can worsen ground-level pollution, most notably ozone (12-14), leading to diminished lung function, increased health care utilization and premature death. Individuals with COPD, CVD, diabetes and chronic ozone exposures are at particular risk (15). The highest burden of these conditions falls disproportionately on lower-income members of society, who frequently reside in more polluted areas (16). Climate change can also lead to higher atmospheric concentrations of fine particulates (PM₂.₅) (17,18). The predicted increase in temperatures threatens our ability to meet health-based air quality standards in the future.

WILDFIRES (ALL RESPIRATORY AND CVD)

Wildfires cause episodes of the worst air pollution that most Canadians will ever experience. Higher temperatures and increasing drought contribute to greater wildfire risk, and recent analyses by the Canadian Forest Service suggest that annual average fire activity could double by the end of the century due to climatic changes (19). This increase in fire risk is driven by warmer spring and summer temperatures, reduced precipitation and snowpack, earlier snowmelt and prolonged summer fire seasons at higher elevations (20). Warmer temperatures also put forests at risk for new and more widespread threats that further increase fire risk. For example, the mountain pine beetle has devastated lodgepole pine in British Columbia (BC) and may threaten other areas of the country (21). In fact, the annual average area burned in BC has increased drastically since the beginning of the infestation. The 2014 fire season was extreme throughout Western Canada, with >4.2 million hectares burned in >3500 fires west of Manitoba. While 40% of these fires were in BC, 80% of the burned area was in the Northwest Territories, where much of the population was exposed to dense smoke for extended periods of time.

Wildfire smoke is a complex mixture of particulates and gases that are known to have acute and chronic health effects (22,23). Most of the epidemiological research focuses on increased PM₂.₅ during smoke episodes, which has been associated with a spectrum of acute respiratory impacts (24,25) including symptoms of pain, irritation, cough and...
and chronic impacts of wildfire smoke each year (35). These health mated that an average of 339,000 deaths could be attributed to the acute development of chronic diseases (34). One recent worldwide study estimated that a large proportion of premature deaths could be attributed to lifetime exposure to PM2.5, contributing to increased rates of chronic respiratory and CVDs in the population (33). As emissions from transportation and industrial sources come under better control, we expect that wildfire smoke will play an increasingly important role in lifetime exposure to PM2.5 and, therefore, in the development of chronic diseases (34).

Recent studies have highlighted the importance of indoor air pollution, particularly for vulnerable populations such as children and adults. However, we know from the literature on urban air pollution that increased annual average PM2.5 concentrations are associated with increased rates of chronic respiratory and CVDs in the population (33). As emissions from transportation and industrial sources come under better control, we expect that wildfire smoke will play an increasingly important role in lifetime exposure to PM2.5 and, therefore, in the development of chronic diseases (34).

One recent worldwide study estimated that an average of 339,000 deaths could be attributed to the acute and chronic impacts of wildfire smoke each year (35). These health threats could increase in the future as climate change exacerbates wildfire risks in Canada and around the world (36).

**CHANGES IN POLLEN RELEASES (ASTHMA AND ALLERGIC RHINITIS)**

Aero-allergenic plant pollen production and distribution is impacted by climate change, with several-fold increases in tree, grass, and weed pollen demonstrated under higher carbon dioxide concentrations (37,38) and with extended growing seasons. In midwestern North America between 1995 and 2009, ragweed pollen production increased up to 27 pollen days over the year (39). Increases in ambient pollen concentrations are associated with higher rates of allergic sensitization, higher health care utilization and large increases in over-the-counter allergy medication sales (4,12,40-45). Drought conditions are also predicted to increase, and can worsen these impacts as more pollen, dust, and particulates become airborne in dry conditions.

**HEATWAVES (COPD, CVD)**

Over the past 60 years, average annual temperatures in Canada have increased by >1.5°C (6). During multiday heatwave periods, additional deaths can range into the tens of thousands, as in the 2003 European and 2010 Russian heatwaves, among other notable events. Extreme heat increases short-term premature mortality and morbidity from a variety of causes, including those directly heat-related (heat stroke, heat syncope, heat edema, etc.) and a range of cardiovascular, respiratory, kidney and other illnesses (7,46,47). Increased temperature variability can also increase mortality among elderly patients (48), even in typically moderate climates such as Vancouver, BC (49).

**STORMS, FLOoding AND MOULD EXPOSURE**

Climate change is predicted to increase the intensity of storm events. Thunderstorm activity has been associated with asthma exacerbations in North America, Europe and Australia (50,51) due to the breakage and wide dispersion of pollens by the turbulent atmosphere. More intense storms also lead to increased precipitation, which has been observed across most parts of Canada over the past 60 years (6). More precipitation will also lead to more flooding (52), which threatens health infrastructure, even in wealthy countries. Patients requiring mechanical ventilation and intensive care are particularly vulnerable due to the challenges posed by evacuation and power outages (53). Multiple health care facilities were evacuated during the unprecedented 2013 floods in Alberta (www.direcaptcha.org/presentations/20140107/20140107_tom_watts.pdf), although specific impacts of the floods have not been published to date. Resource-poor facilities are likely to be even more vulnerable to extreme weather threats.

Floods and persistent dampness in homes can promote microbial growth, particularly moulds. High indoor/outdoor mould ratios were observed in the months following Hurricanes Rita and Katrina, indicating the potential for high indoor exposures (54). Mold levels may increase under climate change due to increased moisture in building materials and indoor dampness, increased temperatures and elevated carbon dioxide concentrations that encourage growth (54,55-57). In immune-competent individuals, respiratory illness associated with mould exposure is due to fungal elements that may be allergens or respiratory irritants, leading to exacerbations of allergic rhinitis and asthma (58). In immune-compromised individuals or those with concomitant pulmonary disease, fulminant fungal infections, such as aspergillosis, may ensue (59).

**MITIGATION AND CARDIORESPIRATORY HEALTH**

Mitigation of greenhouse gas (GHG) emissions to reduce future impacts is a critical challenge for society; however, adaptation to the inevitable increases in temperature will also be required. There is significant uncertainty about the range of projected average surface temperature increases in the future; this uncertainty increases with efforts to predict more local changes (1). There is even greater uncertainty in predicting precipitation (1). Some of this is due to the fact that we cannot accurately project future human behaviour that drives GHG emissions. Although societal efforts to achieve meaningful GHG reductions targets will be challenging, the benefits to cardiorespiratory health are significant and can be more immediate and tangible than reductions in GHGs (60). These include reduction in health-harming copollutants emitted with OXEs, and reduction in natural hazards such as wildfires and floods. The improvements in health have already been observed in indoor drying and drying (56) and cooling (57). Mortality reductions are being reduced in Europe, including in electricity generation and household energy use, transportation, food production and agriculture (60). Cobenefits include increased physical activity, reduced air pollution, more efficient and available food production, reforestation and improved overall quality of urban living (61). As noted in a special issue of The Lancet, “The news is not all bad” (62).

**CONCLUSIONS**

It is difficult for individuals to feel empowered in the face of something as vast and daunting as climate change. We can make personal choices and contribute to community efforts, but the challenge will continue to involve large energy infrastructure and be global in scope (63). Nevertheless, respirologists can play an important role because climate change will significantly affect cardiorespiratory health and is, therefore, an issue of considerable importance to individuals and governments. To date, human health, particularly cardiorespiratory health, has not been central to the climate change and energy dialogue in Canada. Many Canadians may not be well informed about direct threats to their cardiorespiratory health from the increased wildfires, hot weather events, air pollution, flooding, mould and longer pollen seasons that are predicted over the coming decades. Respirologists have a unique opportunity to build public interest in this issue by making it relevant to something in which most individuals have profound interest: protecting the health of their families now and for future generations.

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Takaro and Henderson

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