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MEDICAL EDUCATION

Climate Change and Human Health 101

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Climate change poses real health risks for U.S. populations [1]. Through rising temperature, changes in the hydrologic cycle, and sea level rise, climate change is projected to increase the frequency and intensity of heat waves and other extreme weather events (including floods and droughts); alter the geographic range and incidence of climate-sensitive vector-, food-, and waterborne diseases; increase diseases associated with air pollution and aeroallergens; and add to malnutrition in many regions. Often not the *sole* cause of increases in the burden of climate-sensitive health outcomes, climate change interacts with other public health stresses.

Understanding the full range of the health risks of climate change is beyond the scope of this article; for more information, the reader is referred to assessments recently conducted in the United States, Canada, and internationally or to a publication from the Ontario College of Family Physicians aimed at educating family physicians on climate change and health issues [1-4]. Many of these health risks—such as cardiorespiratory illnesses associated with or exacerbated by elevated concentrations of ground-level ozone or injuries and deaths from windstorms and floods—are familiar to most health care professionals. Other risks, however, could challenge health care professionals if unfamiliar climate-sensitive health outcomes become more common, change their distribution, or reemerge.

Greenhouse Gases

The uneven warming of the Earth's surface is the principal driving force for weather and climate, with complex and changing atmospheric and oceanic patterns redistributing solar energy from the equator to the poles. Atmospheric greenhouse gases (including water vapour, carbon dioxide, methane, nitrous oxide, and halocarbons) absorb and reradiate back to the surface some of the solar radiation emitted by the Earth, raising the surface temperature considerably. Increasing the atmospheric concentrations of greenhouse gases will cause further warming.

Carbon dioxide is a central anthropogenic greenhouse gas. It is not destroyed chemically but removed from the atmosphere through multiple processes that transiently store the carbon in land and ocean reservoirs and ultimately in mineral deposits [5]. Natural processes currently remove about half the incremental anthropogenic carbon dioxide added to the atmosphere annually. The balance is removed over 100 to 200 years [6]. This inertia in the climate systems means the Earth will inevitable endure decades of climate change, even with aggressive reduction of greenhouse gas emissions. About 75 percent of the anthropogenic carbon dioxide emissions to the atmosphere during the past 20 years were due to fossil fuel burning, with most of the rest due to land-use change, especially deforestation [5].

Over the past 100 years, the global average surface temperature rose by 0.74 degrees C, with most of the warming attributable to human activities and with the 1990s being the warmest decade [5]. The linear warming trend over the past 50 years (0.13 degrees C per decade) is nearly twice that for the last 100 years. Under a range of scenarios of greenhouse gas emissions, the global mean surface temperature is projected to increase by 1.1 to 6.4 degrees C by 2100. The projected rate of warming is much greater than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years.

Heat Waves

The risk of heat waves is generally not well appreciated by the health care community or the public. Heat is the major weather-related cause of death in the United States. From 1999 to 2003, 3,442 reported deaths resulted from exposure to extreme heat, 66 percent of them males [7]. Cardiovascular disease was recorded as the underlying cause of death in 57 percent of cases in which hyperthermia was a contributing factor. Approximately 70 percent of these heat-related cardiovascular deaths occurred among people with known chronic ischemic heart disease. Other underlying causes of heat-associated death included unintentional poisonings in 29 percent of deaths; endocrine, nutritional, and metabolic disorders in 3 percent of deaths; and all other underlying causes, including infection and psychiatric disorders, in 11 percent of deaths. The state with the highest average annual hyperthermia-related death rate was Arizona (1.7 deaths per 100,000 population), followed by Nevada (0.8), and Missouri (0.6). During the 2006 heat wave in California, heat-related emergency department visits increased more than sixfold and hospitalizations increased more than tenfold [8].

About 40 percent of heat-related deaths occur in adults over the age of 65 [7]. Members of this population are more vulnerable because of intrinsic changes in their thermoregulatory systems and the use of drugs such as diuretics, stimulants, beta-blockers, anticholinergics, digitalis, barbiturates, and others that interfere with normal homeostasis [9]. In addition, age correlates highly with increasing illness, disability, and reduced fitness, all of which heighten vulnerability to heat.

Simply informing individuals that they are at greater risk during a heat wave is insufficient. As homeostasis is impaired, the elderly may not be aware that they are becoming ill and therefore may not take appropriate actions to reduce their heat exposure. A survey of adults over the age of 65 in four cities (Dayton, Ohio; Philadelphia; Phoenix; and Toronto, Canada) found that 90 percent were aware that a heat wave early warning had been issued within the previous week, and approximately three-quarters could name at least one action they should have taken to reduce their heat-related risk—yet less than 50 percent actually changed their behavior [10]. The health care community should develop more active outreach to those at increased risk during heat waves, in conjunction with local public health and meteorological departments and services.

Infectious Diseases

Increasing temperatures and changes in the hydrologic cycle provide opportunities for many pathogens and vectors to change their geographic range, replication rate, and transmission dynamics. Climate is a primary determinant of whether a particular location has the environmental conditions suitable for the transmission of several vector-borne diseases, including dengue fever, St. Louis encephalitis, and West Nile virus. A change in temperature may hinder or enhance vector and parasite development and survival, thus lengthening or shortening the season during which vectors and parasites survive. Small changes in temperature or precipitation can cause previously inhospitable altitudes or ecosystems to become conducive to disease transmission (or cause currently hospitable conditions to become inhospitable).

For example, a retrospective review of three independent patient databases in Alaska reported a statistically significant trend in the number of patients seeking care for insect reactions over 14 years [11]. Fairbanks had a fourfold increase in patients in 2006 compared to the 1992 to 2005 period, and Anchorage had a threefold increase between the 1999 to 2002 and 2003 to 2007 periods. A review of the Alaska Medicaid database from 1999 to 2006 also showed statistically significant growth in medical claims for insect reactions in five of six regions, with the largest percentage increases occurring in the most northern areas. Since 1950, average annual and winter temperatures in Alaska rose 3.4 degrees F and 6.3 degrees F, respectively. Average winter temperatures increased at least 6 degrees F in regions that reported a significant rise in bite or sting events, leading the authors to conclude that warmer temperatures may have been a contributing factor.

Climate change also may facilitate the emergence of infectious diseases. For example, *Vibrio parahaemolyticus*, the leading cause of seafood-associated gastroenteritis in the United States, is typically associated with the consumption of raw oysters gathered from warm-water estuaries. In 2004, an outbreak occurred in Alaska where the consumption of raw oysters was the only significant predictor of illness; the attack rate among people who consumed oysters was 29 percent [12]. All oysters associated with the outbreak were harvested when mean daily water temperatures exceeded 15.0 degrees C (the theorized threshold for the risk of *V. parahaemolyticus* illness from the consumption of raw oysters). Between 1997 and 2004, mean water temperatures in July and August at the implicated oyster farm increased 0.21 degrees C per year; 2004 was the only year during which mean daily temperatures did not drop below 15.0 degrees C. The outbreak extended by 1,000 km the northernmost documented source of oysters that caused illness due to *V. parahaemolyticus.* Rising temperatures of ocean water may have contributed to one of the largest known outbreaks of *V. parahaemolyticus* in the United States.

Conclusion

The inherent inertia in the climate system implies that climate will continue to change for decades after significant reductions in greenhouse gas emissions are achieved, committing future generations to increasing climate-related health risks. Basic understanding of climate change and its potential health impacts should be included in training and professional development courses for health care professionals to reduce current and projected injuries, illnesses, and deaths due to climate-sensitive health outcomes.

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