

Perspective

Impact of Climate Change on Elder Health

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Demographers predict human life expectancy will continue to increase over the coming century. These forecasts are based on two critical assumptions: advances in medical technology will continue apace and the environment that sustains us will remain unchanged. The consensus of the scientific community is that human activity contributes to global climate change. That change will degrade air and water quality, and global temperature could rise 11.5°F by 2100. If nothing is done to alter this climatic trajectory, humans will be confronted by a broad spectrum of radical environmental challenges. Historically, children and the elderly adults account for most of the death toll during times of severe environmental stress. This article makes an assessment from a geriatric viewpoint of the adverse health consequences that global climate change will bring to the older segments of future populations in the United States.

Key Words: Climate change—Environmental consequences—Geriatric population—Mortality risks—Life expectancy forecasts.

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A basic tenet of ecology is that organisms are products of their environment. Put another way, the biology of a species is molded by the environment from which it emerged (1). Further, a species' risk of extinction increases when its environment or habitat is modified, reduced, fragmented, or lost (2). As of January 2012, 41% of the world's amphibians, 13% of the birds, and 25% of the mammals are identified as threatened (3). The point is that organisms are adapted to an environment and when that environment undergoes rapid change, the risk of extinction depends on whether their physiology possesses the adaptive capacity to keep pace with those changes.

Although technology is not unique to humans, no other species, past or present, has achieved the technological sophistication of *Homo sapiens*. Every new generation of humans is more technologically advanced than all previous generations. Up to now, most of those advancements have been directed toward modifying the natural world around us. Those modifications have led to (a) unprecedented population growth, (b) unprecedented increases in life expectancy at birth (a metric of population health), and (c) unprecedented survival to older ages (population aging). All three of these unprecedented achievements are by-products of technologies that have dramatically reduced the mortality risks associated with avoidable mortality (eg, infectious and parasitic diseases, predation, natural disasters, famines, and/or drought).

Humans, even preindustrial aboriginal humans, have physically altered the environments within which they lived. Postindustrial technological advancements have greatly magnified those environmental alterations. These man-made changes (eg, highways, dams, cities) are so profound that they are now visible to the naked eye from outer space (4). However, the impact of these changes on aspects of the environment (air and water) that most of us take for granted is no less profound and no less important. The benefits of this technological revolution are indisputable. Over the last century, the leading causes of death have transitioned from infectious and parasitic disease to heart disease, cancer, chronic lung disease, and stroke (5). Diseases like some cancers that historically killed acutely have been transformed by medical interventions into less lethal chronic diseases. In so doing, technologies have augmented human biology and increased human life expectancy.

However, scientists around the world have also come to a consensus that our technologies have adversely accelerated an ongoing natural cycle of global warming. A comprehensive examination of health and longevity at a global level (6) is beyond the scope of this article. Instead, our focus is on the United States because the National Academy of Sciences has created an extensive collection of interagency expert panel reports that provide comprehensive examinations of the predicted environmental and infrastructure

consequences of climate change in the United States between now and 2100 (7). Finally, because this article is written from a gerontological perspective, our goal is to provide a condensed summary of the academy literature in order to speculate on how climate change may affect the health and longevity of the older segments of future U.S. populations.

AIR

Breathing is not optional; therefore, the quality of the air we breathe does affect our health. In the United States, the Environmental Protection Agency is the regulatory agency responsible for identifying airborne health risks, establishing air quality standards to reduce those risks, monitoring pollution levels to confirm they meet those standards, and reporting their findings to government entities and the general public (8). Air pollution has many faces (various mixtures of gases and particles), many sources (power-generating facilities and industrial, agricultural, vehicular, and weather-related secondary pollutants), and many health (respiratory illnesses, cardiovascular disease, susceptibility to infections, cancer) and environmental (damage to vegetation, disruption of plant growth, inhibition of CO₂ uptake) consequences.

The good news is that since 1990, there has been a consistent and significant improvement in air quality in the United States as measured by drops in the levels of common pollutants (ozone, particle pollution, lead, nitrogen oxide, carbon monoxide, and sulfur dioxide) and their precursors. This national trend does not apply to all locations (counties) within the United States; there are areas of the country that do not meet national ambient air quality standards throughout the entire year. In addition, toxic air pollutants (diesel particulates, formaldehyde, and benzene) remain a significant concern due to their probable links to cancer and respiratory illnesses.

The biggest concern, however, is the 7% increase in greenhouse gases (CO₂, methane, N₂O, and O₃) between 1990 and 2010 that are impeding solar energy from escaping the earth's atmosphere and, therefore, contributing to global warming. In fact, as this article was being written the most important heat-trapping gas, CO₂, has surpassed 400 parts per million—a level not seen in more than 3 million years (9). Evidence like this has led the scientific community to conclude that human activity is contributing to global climate change. At the current rate of global warming, improvements in U.S. air quality will reverse and become hazards to both public health and public welfare.

WATER

Water quality seems like a straightforward issue, but it is not. Potential drinking water can come from lakes, streams, rivers, or aquifers. That water, in turn, travels through treatment plants that may be large scale for towns and cities or a

filtration system in the basement of a single home attached to a well. The filtered water has to pass through a distribution system (pipes) that may be relatively new or very old (10). Water can be reused, but that raises new concerns about health and ecological risks (11). In addition, water quality affects humans in many ways other than simple consumption (recreation, barge transportation on large rivers, pesticide runoff, oil spills, hurricanes, ecological damage).

The immense diversity of sources of water and its contaminants makes it more difficult to monitor and assess than air quality. Nevertheless, the Environmental Protection Agency (12) concluded that 41.9% of river and stream miles were in “poor” biological condition, 24.9% in “fair” condition, and 28.2% in “good” condition. Aquifers, however, are a concern not only in terms of whether water is being used faster than it is replenished but also the growing appearance of agricultural and industrial contaminants in them (eg, pesticides and hydraulic fracturing contaminants). Although water quality in general remains an issue of concern, water supply (in most but not all regions of the United States) does not—92% of the annual precipitation in the United States is not appropriated for human use, and despite population growth, water usage has leveled off.

As a final perspective on the quality of water consumed by humans in the United States, it should be viewed as a “complex mixture of at least 600 identified disinfectants and disinfectant by-products as well as countless unidentified ones” whose “toxicological effects are largely unknown” (13). Regarding our major rivers, their “poor” to “fair” evaluation can, in part, be attributed to the chemical runoff (mainly nitrates and phosphates) and hypoxia (oxygen deprivation) that degrades water quality and adversely affects aquatic ecosystems and the diverse range of organisms that depend on them. Reclamation attempts have made progress, but slowly. The lesson learned is that it is easier to protect ecosystems than to restore them.

CLIMATE CHANGE

After lengthy debate and considerable denial, the scientific community has come to an unequivocal consensus that “global warming observed over the past 50 years is due primarily to human-induced emissions of heat-trapping gases” (14). At the present rate of U.S. carbon emissions, global average temperature in 2100 is expected to rise between 2°F and 11.5°F—with the latter projection more probable than the former. This dramatic temperature change will produce equally dramatic changes in severe weather events, ecological disruptions, ecosystem destruction, species extinction, and the adverse impacts these climate changes will have on humans.

The litany of adverse consequences that could occur within the lives of people alive today is both staggering and sobering: increased weather-related damage to infrastructure, loss of land and wetlands to rising sea levels, entire

forests either lost or converting to entirely different types of forest, large insect infestations, more wildfires, loss of cold water fisheries, ocean acidification, more frequent and severe heat waves, flow rate changes in our rivers and streams, drought and scarce water throughout the southwestern parts of the country, loss of biodiversity via the extinction of species unable to escape or adapt to these radical environmental changes, an increase of disease pathogens and invasive pests and plants, a degradation of water quality (eg, algal blooms and drought-induced concentration of pathogens), and an increase in air pollution and airborne allergens (pollen and mold).

The U.S. Global Change Research Program made projections based upon three scenarios of temperature increase ranging from a 2°F to 11.5°F rise between now and 2100. These scenarios were based on the assumption that “policies specifically designed to address climate change” will not occur. If achieved, the upper range of the temperature scenarios would produce catastrophic consequences for humanity and the ecosystems that sustain us.

Unfortunately, as the debates over climate change continue, one thing becomes abundantly clear. The vast majority of the U.S. population and our elected officials totally ignores the warnings about the human consequences of global climate change. Corporations have resisted cap and trade policies that would securitize carbon emissions and create an economic environment that incentivizes a reduction of overall carbon emissions. Global warming is not a U.S. phenomenon; it is a global phenomenon. If the major carbon-emitting entities in the United States cannot cooperate to lower emissions, then the cooperation needed to adequately address “global” warming has little chance of materializing. Thus, the key question from a human perspective is whether and how humans can adapt to the radical environmental challenges looming in the near future.

IMPACT OF CLIMATE CHANGE ON ELDER HEALTH

Regardless of species, the most common pattern of age-related mortality is U-shaped, high levels of mortality among the youngest and oldest segments of a population. The implication is that children and the elderly adults are more vulnerable to death. We are living in a world of population aging; older people are rapidly becoming a progressively larger segment of the population in developed countries. In other words, human technology and culture are creating a large and growing subpopulation that is especially vulnerable to the consequences of climate change. It is this latter population that was the primary motivation for writing this article.

The elderly adults have a complex relationship to the environment. They are more sensitive to changes in the environment and exposure to toxins, noxious agents, and infectious agents. This greater sensitivity is a by-product of a lower physiological reserve capacity, slower metabolism,

and a more slowly responding immune system. They also have a higher disease burden (morbidity) than people at younger ages. The cumulative effect of this increased disease burden makes specific organ systems less able to tolerate stress. For example, the central nervous system of the elderly adults is more sensitive to high internal temperatures, which can cause memory loss, confusion, and delirium. The cardiovascular system also has to work harder in the heat, increasing the risk for myocardial infarction. High prevalence conditions like chronic renal failure where fluid regulation is essential make elders particularly susceptible to dehydration, acute renal failure, liver shock, and rhabdomyolysis among other life-threatening challenges.

In warnings of the Air Quality Index, older persons are included in the category of sensitive populations, including infants and children, and those with cardiorespiratory disease. The elderly adults experience adverse health effects at lower concentrations of air pollutants. Periods of high levels of air pollution are related to increased numbers of hospitalizations for cardiovascular disease (15) and lung disease (16) in older persons. In large urban areas like Los Angeles that are prone to microclimate air inversions (smog), increasing levels of air pollutants coupled with the increasing temperatures linked to human-induced climate change may be expected to exacerbate air quality-related health risks among the elderly adults.

Ambient air temperature is another important health issue to older persons. The combination of high ambient air temperature, humidity, and the diminished ability of the elderly adults to maintain thermal homeostasis allows core body temperature to reach dangerous and even life-threatening temperatures. Sweating is normally an effective compensatory mechanism but with high humidity perspiration that evaporates is replaced by sweat rivulets that do little to lower core temperature and can cause rapid dehydration in the elderly adults.

Mortality risk from high ambient temperatures is not inconsequential. In the United States, more than 8,000 people died from excessive heat exposure between 1979 and 2003 (17). In fact, more people died from high ambient temperature than from all other natural disasters (hurricanes, tornadoes, floods, and earthquakes) combined (18). Approximately 70,000 people died in Europe during the summer heat wave of 2003. By way of contrast, the official death toll from Hurricane Katrina in 2005 was 1,836.

Cities, especially large cities, are exemplars of how technology has created uniquely human environments that isolate us from the natural world. This innovation has contributed to increases in life expectancy and remarkable population growth. However, these urban environments also create unique health risks. One of the most prominent of these is hot spots (“heat islands”) within large cities and the death toll they take among the elderly adults. Even if global warming did not exist, heat-related fatalities will increase as the proportion of people in the United States beyond age

65 increases from 12.4% in 2000 to 20% in 2060 (19). Not only will older people be exposed to heat risk but more of them will likely be living in cities where the risk is greatest if, as predicted, “60% of the global population will live in cities by 2030” (20).

A progressive concentration of people into large urban cities has significant health implications. Consider the heat wave that struck Paris, France, in 2003 (21). Satellite images revealed a 1° to 2° temperature gap between urban Paris and a rural suburb during night and day, respectively. Despite that seemingly small temperature differential, elderly city dwellers experienced twice the mortality risk of their suburban age- and gender-matched counterparts. This mortality disparity was attributed to heat-trapping concrete and cement, which cooled down more slowly during Paris city nights than in the more green vegetated suburbs. The implications of such heat waves are stark. Measured by mortality, it was the worst natural disaster in contemporary France, and events like this are going to be more common in the future (22).

One of the hallmarks of public health success in the United States has been near universal access to reliable safe drinking water. By way of example, typhoid and cholera—two of the most deadly waterborne illnesses in the world—were virtually eliminated in the United States over the course of the 20th century. Looking forward, two 21st century challenges could compromise this success: deteriorating water filtration and distribution systems and climate change. The Environmental Protection Agency estimates that \$151 billion is needed to address the cumulative deficits arising from a half century of inadequate maintenance and repair of the nation’s public water infrastructure (23). The health risks associated with this infrastructure degradation (resurgence of waterborne and pollutant-related disease) will be augmented by anticipated water-related changes (chemistry, temperature, quantity, quality) caused by climate change (24). By some estimates, as many as 135 million people worldwide will perish from water-related disease in the first two decades of the 21st century (25), and the United States is not immune to this risk. The elderly adults are particularly susceptible to gastrointestinal pathogens, many of which are waterborne (26). For example, a recent Centers for Disease Control and Prevention study revealed that gastroenteritis-associated deaths rose from about 7,000 to more than 17,000 yearly over the past 8 years with 83% of those deaths occurring in the 65-plus age group (27).

CONCLUSIONS

With the advent of new technologies, people who would have died at early ages have now been successfully ushered into the older region of the lifespan distribution. Lowering the barrier to this extended survival creates (a) populations that are more heterogeneous in a health sense than in the past (28), (b) more people struggling (65% of Medicare beneficiaries) with multiple chronic health conditions (29),

(c) a more complex and more costly medical milieu that physicians and other health care providers must navigate (30), and (d) from the vantage point of this article, an expanding population of older individuals vulnerable to the adverse health consequences attributed to climate/environment change.

A realistic appraisal suggests climate change between now and 2100 will outpace the ability of human technology to compensate for that change. With a dramatic migration of humans into rapidly growing cities, it will be exceedingly difficult to transform existing infrastructure to a green infrastructure while simultaneously expanding infrastructure to accommodate the new arrivals. Nevertheless, there is a need to mitigate the health challenges imposed by climate change. Many of the elder-friendly mitigation strategies are consistent with ongoing efforts by urban planners to create ecofriendly urban environments such as reducing the surface area covered by concrete, converting tops of buildings into garden plots, requiring a specified ratio of green space to concrete, encouraging landlords to reserve lower floor apartments for the elderly adults and to improve the passive ventilation of heat in apartment complexes, hastening the pace of ecofriendly transportation, providing incentives to increase the proportion of geriatricians and as is currently done with fire and police stations; elder service centers should be uniformly distributed throughout large urban cities. Although progress in helping humans adapt to climate change will occur and may be partially successful, the bigger unsolved problem will be how to maintain or mitigate the damage that is already occurring to the natural ecosystems that sustain us.

Although components of the environment were discussed separately, they are, in reality, part of an interacting system. As such, the elderly adults are not affected as much by an isolated environmental threat but by an ensemble of threats that stress a biology whose adaptive capacity has been compromised by aging. Demographers have predicted that human life expectancy will continue to increase over the coming century (31,32). These optimistic predictions, however, are based on two critical implicit assumptions, namely, advances in medical technology will continue apace and the environment that sustains us will remain unchanged or at least not change in ways that produce adverse health consequences. Although it is difficult and even frightening to consider the human impact arising from the myriad environmental changes predicted by scientists during the coming century, it is essential that we do so.

Many of these radical environmental changes, such as increases in air pollution and airborne allergens, increases in disease pathogens, increases in the frequency and severity of heat waves, and degradation of water quality will have profound health consequences for elderly adults. Unless the major carbon-emitting entities in our world agree to cooperate in order to lower carbon emissions significantly in the near future, humans will have to adapt very quickly to

radical environmental changes. The time has come for all humanity to confront this impending challenge and begin developing plans for protecting the subpopulation of older people in all our societies who are especially vulnerable to the adverse health consequences that global climate change will bring.

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