Review Article

Climate change and human illness: a hot topic?

Paul Torpiano

Abstract

Global climate change, now proven to occur under the influence of human activity, affects human health and illness. Aside from the risk of natural disasters and diminishing fresh-water supply and arable land, climate change maintains a complex relationship with both communicable and non-communicable forms of illness. The epidemiology of infectious diseases, whether viral, parasitic, or bacterial, has shown to change under the influence of climate, particularly in the case of vector-borne zoonoses. Non-communicable disease, , including allergic, respiratory, cardiovascular and dermatological, are also influenced by global and regional changes in climate. While undoubtedly of increasing importance, the role of the clinician in educating communities on the negative health impact of climate change, as well as the potential benefit of sustainable healthcare policy, are yet to be defined.

Paul Torpiano MD, MRCPCH (UK), MRCP (UK), PGDip PID (Oxford)
Department of Paediatrics
Mater Dei Hospital
Msida, Malta
paul.torpiano@gov.mt

Background

That climate change is real, and that it is anthropogenic, is now beyond doubt. Evidence to this effect is now in abundance: rising seas levels, otherwise inexplicable patterns of global warming over the last 50 years, reductions in arctic sea ice, an increase in the frequency of intense tropical cyclones.[1] Scientists now forecast that global temperatures may rise between 1.4-5.8ºC by the year 2100.[2] Global climate change is caused by several interacting mechanisms: human production of greenhouse gases, stratospheric ozone depletion, and increasing volcanic activity.[2] Since the mid-19th century, human activities have generated increasing amounts of greenhouse gases, including carbon dioxide, methane, and nitrous oxide, resulting in increased average temperature.[3] The effects of this include soil degradation and loss of agricultural land, desertification, loss of biodiversity, and declining fresh-water resources.[3] The global conversation has now shifted, with the focus now on the impact of climate change on human health, and what can be done to mitigate this.

Many of the negative effects of climate change are self-evident. Changing patterns of rainfall, leading to drought and mass dehydration in some areas, while fierce tropical cyclones batter others, puts lives at risk.[4] The same can be said of tsunami, tectonic and volcanic activity, floods, and other natural disasters, the frequency of which are influenced by widespread climate change.[4] Aside from deaths from drowning or trauma, natural disasters can damage global food supplies, leading to famine, and lead to large-scale migration of at-risk populations.[4] But beyond natural disasters, how does climate change influence the epidemiology and outcome of human illness?

Predictions from the past

Warnings of the potential for climate change to impact human health are not new. In a 1991 paper entitled 'Anticipated public health consequences of global climate change', Janice Longstreth suggested that rising temperatures could cause decompensation in those with chronic cardiovascular or respiratory disease. She flagged up the potential for climate change to cause an increase in asthmatic exacerbations, lung malignancy, and vector-borne illnesses, while suggesting that the impact on forests and wetlands could influence the airborne concentration of allergens such as moulds and pollens.[5] This, in turn, could alter the epidemiology of eczema, asthma, allergic rhinitis, and other atopy-related illness.[5] Rising sea levels secondary to melting polar ice caps could restrict habitable terrain, leading to overcrowded residential areas.[5] Urbach et al indicated that increases in ultraviolet radiation could cause surges in skin malignancy, cataracts, and even alter the immune system.[6] Other reports highlighted the potential for climate change to affect fertility rates, neonatal development, perinatal mortality, and preterm birth rates.[5,7-8] Kalkstein et al used mathematical modelling based on global warming to warn of significant increases in weather-related mortality,[9] while McGeehin et al proposed that mortality and morbidity secondary to climate change would depend on the readiness of a population to adapt physiologically and behaviourally to temperature changes. In this model, the elderly, young children, and those of low socio-economic status were shown to be particularly vulnerable.[10]

Communicable disease

Changes in temperature and rainfall patterns, particularly extreme weather events, enhance the spread of infectious diseases.[11] The life cycles and epidemiology of infectious organisms are intimately related to the environment, and as such, are subject to the influence of climate. There is convincing evidence that diarrhoeal diseases increase with rising temperatures, with an estimated increased risk of 3-11% for every 1ºC of environmental temperature rise.[12] *Salmonella sp.* and *Vibrio cholerae*, both important causes of diarrhoeal disease in low and middle income countries, proliferate more rapidly at higher temperatures.[13] Changing rainfall patterns may cause floods, with subsequent epidemics of leptospirosis, campylobacteriosis and cryptosporidiosis.[3] While increasing global temperatures could be expected to lead to a fall in Winter respiratory infections, the relationships between the climate and the causative pathogens appear to be complex. In fact, fluctuating temperatures may increase the incidence and mortality of viral respiratory infections amongst vulnerable populations, such as older adults and children.[14]

Pathogens transmitted by vectors are particularly sensitive to climate change, since they are often carried by cold-blooded intervertebrate hosts whose temperature reflects that of the environment.[3] Warmer climates can present more favourable conditions for the completion of a life cycle, as in the case of mosquitos.[3] In addition, climate change will undoubtedly cause behavioural changes amongst the hosts of such pathogens. Such changes could influence migration, feeding, and reproductive behaviour, with the potential to affect human contact with these hosts.[3] A recent report highlighted the importance of climate change and exposure to prairie dogs, a common reservoir for *Yersinia pestis*, as the source of a pulmonary plague outbreak in Colorado.[15] Statistical models defining the relationship between climate change and vectors of other bacterial diseases, such as leptospirosis, have also predicted predict future epidemics.[16] Tick-borne illnesses, such as Mediterranean Spotted Fever, have shown increases in cold regions in recent years, possibly as a result of rising temperatures that encourage egg production and biting behavior amongst ticks.[17] Lyme disease, another tick-borne illness caused by *Borrelia burgdorferi*, has seen its area of endemicity and incidence increase in the United States.[18] Dry weather has also resulted in significantly increased rates, geographic range, and infectious cycles of leishmaniasis in the US, potentially due to northward extension of the rodent reservoir and sand fly vectors, *Lutzomyia diabolica* and *Lutzomyia anthrophora*.[19] Furthermore, climate change has been linked to increases in a number of infectious skin pathologies, including cercarial dermatitis, cellulitis and wound infections with *Vibrio parahaemolyticus* and *Vibrio vulnificus*, and melioidosis.[20]

Malaria, still the most common cause of arthropod-borne infectious disease worldwide, has become endemic at higher altitudes and in new, formerly malaria-free tropical, subtropical and temperate regions. This has most probably occurred under the influence of global warming and increasing precipitation in these areas.[2] The link between malaria and weather patterns has been visible elsewhere: studies in South Asia and South America documented an association between malaria outbreaks and the El Nino Southern Oscillation cycle.[21–23] Such an association has also explained similar outbreaks of dengue fever in these regions.[24] The West Nile virus, which utilizes birds as a reservoir and mosquitoes as vectors, has gained prominence in the Mediterranean area and North America over recent years.[25] The incidence of another viral infection, enteroviral hand-foot-and-mouth disease (HFM), shows correlation with average temperature and rainfall, while humidity has been associated with HFM epidemics.[26]

Non-communicable disease

The influence of climate on non-communicable disease may be less apparent. As alluded to earlier, a changing climate will alter distribution of vegetation and forestation, with a likely impact on pollens and other airborne allergens. Higher levels of carbon dioxide, together with a warmer climate, could cause anticipation in time of the onset of warmer seasons and thus of the concentration of aeroallergens.[12] Studies in the Eastern Mediterranean region have shown that an earlier and longer-lasting presence of aeroallergens exacerbates allergic rhinitis, asthma, and eczema.[27-28] Increases in ambient pollen concentrations are associated with higher rates of allergic sensitization, higher numbers of emergency department visits and hospital admissions for asthma and allergic rhinitis, as well as higher numbers of physician office visits for allergic diseases.[29]

Beyond allergy, the cardiorespiratory system may be vulnerable to climate change by additional mechanisms. A review published in 2007 by the US Environmental Protection Agency concluded that high ozone exposure owing to heat waves was associated with a reduction in lung function and exacerbation of respiratory symptoms in patients with pre-existing respiratory diseases, contributing to premature deaths in people with heart and lung disease.[30] Warmer temperatures appear to increase the concentrations of air pollutants, mainly ozone and particulate matter that are of particular relevance for cardiopulmonary health.[31] A case-crossover study in England and Wales examining the relationship between temperature and the incidence of acute myocardial infarction found that increasing ambient temperatures above a threshold of 20 °C were associated with a higher risk of myocardial infarction occurring as early as 1 to 6 h after exposure.[32] This link between myocardial infarction and higher temperatures has since been described further in a recent systematic review.[33]

Changes in ambient temperature and sun exposure would be expected to influence skin disease. Ozone depletion has resulted in an increased risk of skin cancer, while elevated temperatures alone could result in increased ultraviolet damage to skin, even without changes in ultraviolet light dose.[34-35] A 2ºC temperature rise may increase the number of skin cancers yearly by 10%.[36] Warmer temperatures are also associated with increased time spent outdoors, often without protective clothing or sunblock.[37] Furthermore, warmer oceans generate larger jellyfish populations, with a recent systematic review confirming a worldwide increase.[38] This puts swimmers at increased risk of jellyfish-related stings.

Conclusions

As our understanding of the mechanisms and impact of climate change improves, the knowledge-base surrounding the influence of climate change on human illness will also expand. Research carried out in the last decade has proven correct many of the predictions made earlier concerning how climate change might affect our health, while revealing some surprises about the complex relationship between climate and disease. Both communicable and non-communicable illnesses have been shown to act under the influence of climate. Further research, along with close epidemiological surveillance of disease, will help shed more light on this relevant area of study, and may guide both health and enivironmental policy in the years to come. As the link between climate and disease becomes clearer, so will our responsibility as clinicians to educate patients and communities on the health-related dangers of unsustainable behaviours and global environmental change.[39]

References

1. 9.7 Combining Evidence of Anthropogenic Climate Change - AR4 WGI Chapter 9: Understanding and Attributing Climate Change. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch9s9-7.html#table-9-4. Accessed January 31, 2018.
2. Diaz JH. Global Climate Changes, Natural Disasters, and Travel Health Risks. *J Travel Med.* 2006;13(6):361-372. doi:10.1111/j.1708-8305.2006.00072.x.

3. Rossati A. Global Warming and Its Health Impact. *Int J Occup Environ Med*. 2017;8(1):7-20. doi:10.15171/ijoem.2017.963.
4. Diaz JH. The influence of global warming on natural disasters and their public health outcomes. *Am J Disaster Med*. 2(1):33-42. http://www.ncbi.nlm.nih.gov/pubmed/18268873. Accessed September 23, 2017.
5. Longstreth J. Anticipated public health consequences of global climate change. *Environ Health Perspect*. 1991;96:139-144. http://www.ncbi.nlm.nih.gov/pubmed/1820256. Accessed September 24, 2017.
6. Urbach F. Potential health effects of climatic change: effects of increased ultraviolet radiation on man. *Environ Health Perspect*. 1991;96:175-176. http://www.ncbi.nlm.nih.gov/pubmed/1820263. Accessed January 25, 2018.
7. Keller CA, Nugent RP. Seasonal patterns in perinatal mortality and preterm delivery. *Am J Epidemiol*. 1983;118(5):689-698. http://www.ncbi.nlm.nih.gov/pubmed/6637995. Accessed January 25, 2018.
8. Cooperstock M, Wolfe RA. SEASONALITY OF PRETERM BIRTH IN THE COLLABORATIVE PERINATAL PROJECT: DEMOGRAPHIC FACTORS. *Am J or Epidemiol*. 124(2). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.829.8841&rep=rep1&type=pdf. Accessed January 25, 2018.
9. Kalkstein LS, Greene JS. An evaluation of climate/mortality relationships in large U.S. cities and the possible impacts of a climate change. *Environ Health Perspect*. 1997;105(1):84-93. http://www.ncbi.nlm.nih.gov/pubmed/9074886. Accessed January 25, 2018.
10. McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environ Health Perspect*. 2001;109 Suppl 2:185-189. http://www.ncbi.nlm.nih.gov/pubmed/11359685. Accessed January 25, 2018.
11. McMichael AJ. Globalization, Climate Change, and Human Health. *N Engl J Med*. 2013;368(14):1335-1343. doi:10.1056/NEJMra1109341.
12. Franchini M, Mannucci PM. Impact on human health of climate changes. *Eur J Intern Med*. 2015;26(1):1-5. doi:10.1016/j.ejim.2014.12.008.
13. Pascual M, Dobson A. Seasonal Patterns of Infectious Diseases. *PLoS Med*. 2005;2(1):e5. doi:10.1371/journal.pmed.0020005.
14. Mirsaeidi M, Motahari H, Taghizadeh Khamesi M, Sharifi A, Campos M, Schraufnagel DE. Climate Change and Respiratory Infections. *Ann Am Thorac Soc*. 2016;13(8):1223-1230. doi:10.1513/AnnalsATS.201511-729PS.
15. Foster CL, Mould K, Reynolds P, Simonian PL, Erlandson KM. Clinical problem-solving. Sick as a dog. Solomon CG, ed. *N Engl J Med*. 2015;372(19):1845-1850. doi:10.1056/NEJMcps1411346.
16. Chadsuthi S, Modchang C, Lenbury Y, Iamsirithaworn S, Triampo W. Modeling seasonal leptospirosis transmission and its association with rainfall and temperature in Thailand using time-series and ARIMAX analyses. *Asian Pac J Trop Med*. 2012;5(7):539-546. doi:10.1016/S1995-7645(12)60095-9.
17. De Sousa R, Luz T, Parreira P, Santos-Silva M, Bacellar F. Boutonneuse fever and climate variability. *Ann N Y Acad Sci*. 2006;1078:162-169. doi:10.1196/annals.1374.029.
18. CDC Online Newsroom | Press Release | CDC provides estimate of Americans diagnosed with Lyme disease each year. https://www.cdc.gov/media/releases/2013/p0819-lyme-disease.html. Accessed February 7, 2018.
19. González C, Wang O, Strutz SE, González-Salazar C, Sánchez-Cordero V, Sarkar S. Climate Change and Risk of Leishmaniasis in North America: Predictions from Ecological Niche Models of Vector and Reservoir Species. Galvani AP, ed. *PLoS Negl Trop Dis*. 2010;4(1):e585. doi:10.1371/journal.pntd.0000585.
20. Kaffenberger BH, Shetlar D, Norton SA, Rosenbach M. The effect of climate change on skin disease in North America. *J Am Acad Dermatol*. 2017;76(1):140-147. doi:10.1016/j.jaad.2016.08.014.
21. Bouma MJ, Dye C. Cycles of malaria associated with El Niño in Venezuela. *JAMA*. 1997;278(21):1772-1774. http://www.ncbi.nlm.nih.gov/pubmed/9388155. Accessed January 25, 2018.
22. Bouma MJ, Poveda G, Rojas W, et al. Predicting high-risk years for malaria in Colombia using parameters of El Niño Southern Oscillation. *Trop Med Int Health*. 1997;2(12):1122-1127. http://www.ncbi.nlm.nih.gov/pubmed/9438466. Accessed January 25, 2018.
23. Bouma MJ, van der Kaay HJ. The El Niño Southern Oscillation and the historic malaria epidemics on the Indian subcontinent and Sri Lanka: an early warning system for future epidemics? *Trop Med Int Health*. 1996;1(1):86-96. http://www.ncbi.nlm.nih.gov/pubmed/8673827. Accessed January 25, 2018.
24. Hales S, Weinstein P, Woodward A. Dengue fever epidemics in the South Pacific: driven by El Nino Southern Oscillation? *Lancet*. 1996;348(9042):1664-1665. doi:10.1016/S0140-6736(05)65737-6.
25. Grazzini G, Liumbruno GM, Pupella S, et al. West Nile virus in Italy: a further threat to blood safety, a further challenge to the blood system. *Blood Transfus*. 2008;6(4):235-237. http://www.ncbi.nlm.nih.gov/pubmed/19112739. Accessed January 25, 2018.
26. Liu W, Ji H, Shan J, et al. Spatiotemporal Dynamics of Hand-Foot-Mouth Disease and Its Relationship with Meteorological Factors in Jiangsu Province, China. Jin X, ed. *PLoS One*. 2015;10(6):e0131311. doi:10.1371/journal.pone.0131311.

27. Habib RR, Zein K El, Ghanawi J. Climate change and health research in the Eastern Mediterranean Region. *Ecohealth*. 2010;7(2):156-175. doi:10.1007/s10393-010-0330-1.
28. Balato N, Megna M, Ayala F, Balato A, Napolitano M, Patruno C. Effects of climate changes on skin diseases. *Expert Rev Anti Infect Ther*. 2014;12(2):171-181. doi:10.1586/14787210.2014.875855.
29. D'Amato G, Vitale C, Lanza M, Molino A, D'Amato M. Climate change, air pollution, and allergic respiratory diseases. *Curr Opin Allergy Clin Immunol*. 2016;16(5):434-440. doi:10.1097/ACI.0000000000000301.
30. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper. https://www3.epa.gov/ttn/naaqs/standards/ozone/data/2007_07_ozone_staff_paper.pdf. Accessed January 25, 2018.
31. Spickett JT, Brown HL, Rumchev K. Climate change and air quality: the potential impact on health. *Asia-Pacific J public Heal*. 2011;23(2 Suppl):37S-45. doi:10.1177/1010539511398114.
32. Bhaskaran K, Armstrong B, Hajat S, Haines A, Wilkinson P, Smeeth L. Heat and risk of myocardial infarction: hourly level case-crossover analysis of MINAP database. *BMJ*. 2012;345(dec13 2):e8050-e8050. doi:10.1136/bmj.e8050.
33. Bhaskaran K, Hajat S, Haines A, Herrett E, Wilkinson P, Smeeth L. Effects of ambient temperature on the incidence of myocardial infarction. *Heart*. 2009;95(21):1760-1769. doi:10.1136/hrt.2009.175000.
34. Urbach F. Ultraviolet radiation and skin cancer of humans. *J Photochem Photobiol B Biol*. 1997;40(1):3-7. doi:10.1016/S1011-1344(97)00029-8.
35. Diffey B. Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. *Phys Med Biol*. 2004;49(1):R1-R11. doi:10.1088/0031-9155/49/1/R01.
36. van der Leun JC, de Gruijl FR. Climate change and skin cancer. *Photochem Photobiol Sci*. 2002;1(5):324-326. doi:10.1039/b201025a.
37. Dobbinson S, Wakefield M, Hill D, et al. Prevalence and determinants of Australian adolescents' and adults' weekend sun protection and sunburn, summer 2003-2004. *J Am Acad Dermatol*. 2008;59(4):602-614. doi:10.1016/j.jaad.2008.06.011.
38. Brotz L, Cheung WWL, Kleisner K, Pakhomov E, Pauly D. Increasing jellyfish populations: trends in Large Marine Ecosystems. In: *Jellyfish Blooms IV*. Vol Dordrecht: Springer Netherlands; 2012:3-20. doi:10.1007/978-94-007-5316-7_2.
39. Schwartz BS, Parker C, Glass TA, Hu H. Global environmental change: what can health care providers and the environmental health community do about it now? *Environ Health Perspect*. 2006;114(12):1807-1812. http://www.ncbi.nlm.nih.gov/pubmed/17185267. Accessed January 25, 2018.