Climate Change and Infectious Disease Risk in the Canadian North

- Climate change may lead to infectious disease risk in the Canadian North
- The Canadian North may be particularly vulnerable to these risks because of increased rates and magnitude of warming and traditionally close ties with the land
- Water-borne, food-borne, zoonotic and vector-borne diseases may be influenced by climate change
- There exists little evidence on infectious disease risk and climate change
- Surveillance on climate and infectious disease data in the Canadian North should be improved
- Interventions should be culturally appropriate and tied to traditional indigenous knowledge and practices

Introduction

Anthropogenic inputs to the level of greenhouse gases in the atmosphere have led to planetary warming and a dramatic change to the Earth's climate over the past two centuries. Between 1880 and 2012 the global temperatures increased by an average of 0.85°C, and are forecasted to reach an increase of between 1.5°C to 4°C by the end of the century (1). The effects of environmental change and warming have been the most severe in the northern latitudes compared to other regions. In the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report, scientists found that temperatures in the Arctic had risen at over twice the rate of the global average and may reach increase between 1.5 and 5.8°C by the end of the century (2). Average temperatures over the past 66 years in the Canadian North have increased between 2.1 to 2.6°C (3).

The Canadian North, or Arctic, is defined as the area north of 60° latitude, plus northern Quebec and Labrador (4). It is the traditional homeland of the indigenous peoples who have inhabited the area for thousands of years, and differs from other regions in Canada in that there is a considerable indigenous population compared to the non-indigenous population (5).

Climate warming in the Canadian Arctic has resulted in environmental changes that have wide-ranging impacts. Warmer temperatures have led to reduced extent and thickness of sea ice, delayed sea ice formation, earlier springmelt and melting permafrost, all of which reduce ecosystem functioning and limit the ability of communities in the Arctic to sustain themselves through traditional food practices (3,4). Moreover, Arctic and subarctic areas are expected to see increased frequency, intensity and duration of precipitation (6) accompanied by an increased frequency of extreme weather events (7).

Climate and weather are known drivers of infectious disease (1,4). Changes in precipitation could put communities at increased risk of water-borne infectious diseases (6). Foodborne illnesses may be exacerbated by increased temperatures resulting in food spoilage, increased germination and proliferation of some disease organisms (8). There are many pathways through which climate increases the incidence of vector-borne disease, through shifting the geographic range of disease vectors and promoting favourable conditions for vector and pathogen survival and reproduction (1).

Aside from climate change, there are a set of conditions particular to the Canadian Arctic that may put the mainly indigenous communities living there at increased risk of climate-driven infectious diseases. Indigenous populations have a close relationship with the land, and often depend on their natural environments for their livelihood. Traditional food gathering, hunting practices and reliance on the land may put indigenous populations at increased risk of exposure to water-, food- and vector-borne illnesses. There are existing health disparities between the indigenous communities living in the Canadian North and other Canadians, including the remoteness of the communities, access to health care, infrastructure problems, food security and environmental pollution (7,9). Health inequities and the relationship with the environment, together with a lack of native immunity to disease, make indigenous populations in the Canadian North potentially vulnerable to the effects of emerging infectious diseases (10). With the Arctic warming at more than twice the rate of the global average, this becomes an even more pressing public health concern. As such, this review seeks to examine the risks of infectious disease as a function of climate change in the Canadian North in order to determine knowledge gaps, inform policy and develop appropriate adaptation and mitigation interventions.

Methods

A literature search was conducted using the MEDLINE, EMBASE and Scopus databases. Titles, abstracts and keywords were searched for the following terms: "(Arctic OR Indigenous OR circumpolar) AND (infectious disease* OR communicable disease*) AND (climate OR climate change* OR temperature)". The total number of hits obtained was 140. After limiting the results to those published in English between 2006 to 2016, the number of articles was reduced to 108. Abstracts and titles of these 108 articles were scanned, and if relevant to the research question were included. References of relevant articles were manually searched for other topical studies. A detailed search strategy can be found in the Appendix.

Results and Discussion

Waterborne Infectious Disease

Climatic variables can influence the incidence of water-borne illnesses through changes in water quantity and quality. There is an association between weather events such as heavy precipitation and spring melt that can affect water quality and consequently waterborne disease incidence (6). During periods of heavy rainfall or snowmelt, water turbidity is increased as a consequence of higher water velocity (6). This higher turbidity mixes and transports pathogens into water supplies, increasing the risk of exposure to humans (6). Another mechanism through which climatic factors magnify the risk of infectious disease exposure by allowing pathogens to enter the water supply is through flash floods. This occurs either through contamination of groundwater (7) or through inundation of sewage systems (1).

Hydroclimatic variables have previously been demonstrated to increase the incidence of acute gastro-intestinal illness in two anonymized communities in British Columbia, Canada. Galway et al. (11) conducted an epidemiological study investigating the influence of temperature, precipitation and streamflow on gastro-intestinal illness in two communities in British Columbia, Canada. One of these communities was situated in a snowmelt-dominated watershed, where increasing streamflow in the preceding month was positively associated with the reported cases of acute gastro-intestinal illness. The authors postulated that rapid snowmelt in the community contributed to the peak of the gastro-intestinal illness seen in summer months.

Harper et al. (6) conducted a study exploring the relationship between weather, water quality and infectious gastrointestinal illness in two Inuit communities in Nunatsiavut, Canada. The Inuit communities in Nunatsiavut have already experienced some of the negative effects of climate change. In more recent years, Nunatsiavut has seen increasing temperatures, intensity and frequency of extreme weather events, and more variable precipitation (6). It is known that some residents of this community drink regularly from untreated open water sources. As such, it was theorized that the communities in the study, as well as other Inuit communities, could be at higher risk because of the reliance on untreated, potentially contaminated water sources (6).

Harper et al. (6) found that high water volumes from rainfall and snowmelt predicted higher total coliform and *E.Coli* counts in untreated water from the brooks, and that there was a significant association between water volume and clinic visits for infectious gastrointestinal illness symptoms two and four weeks after. It was estimated that the increased concentration of pathogens in the water was due to overland transport after heavy rainfall and rapid snowmelt.

Foodborne Infectious Disease

Foodborne illnesses have also been associated with conditions created by a changing climate. An upsurge in foodborne disease can be attributed to warmer temperatures that occur in greater magnitude and frequency than previously (1). Salmonellosis, botulism and campylobacteriosis are foodborne illnesses that have been linked with warmer temperatures (1,12). Higher temperatures promote the growth, survival and replication of pathogens responsible for foodborne illness (7).

Since *Clostridium botulinum* spores are germinated at temperatures above 4°C, a warming climate may induce more cases of food-borne botulism. This is especially problematic in the Canadian North due to traditional food practices involving canning, fermentation and food storage (12). Often, indigenous populations living in the Canadian North keep their food from spoiling by storing it on or beside permafrost. The loss of permafrost from warming temperatures leads to food spoilage and food-borne illness. Other food practices such as air-drying of meat also increases the risk of exposure to pathogens as ambient temperatures rise from climate change (12).

Despite these risk factors, few outbreaks have been documented of food-borne illness in the Arctic. One reported outbreak of gastroenteritis has been reported in Alaska as a result of consumption of farmed oysters aboard a cruise ship (13). Using a retrospective cohort design, McLaughlin et al. (13) found that the outbreak caused by *Vibrio parahemolyticus* occurred at a sea water temperatures above 15°C at the time of harvesting the oysters, indicating that higher water temperatures are problematic for oysters and the humans that consume them.

Zoonotic Disease

Climate change and warmer temperatures alter the transmission dynamics of disease that spread from animals to humans. Increased risk of zoonoses comes from warming temperatures that promote the survival of the animal disease host by allowing them to overwinter when they normally would not be able to (14). Consequently, hosts, both susceptible and infected, proliferate in numbers and increase the risk of infecting humans. Climate change could also drive infectious disease in the Arctic through animal hosts migrating further north as warmer temperatures allow them to expand their habitats (14). One such northward moving host is the beaver, which carries the *Giardia lamblia* parasite that can contaminate water sources and cause giardiasis in humans (14). Climate change also drives environmental destruction, leading to perturbations in ecological systems and processes that can further alter the transmission dynamics of zoonotic diseases. By changing the animal-pathogen-human interface, climate change may drive infectious disease by increasing interactions along the interface.

Adding a layer of complexity to zoonoses risk in northern Canadian indigenous populations is the traditional food and hunting practices of the peoples. The reliance on hunting both marine and land animals for food means that there is already a high level of exposure to potentially disease-carrying animals. Species of *Brucella* that cause infection in humans have been found in caribou meat, and more recently in marine mammals such as seals (4). The *Trichinella* parasite in the Arctic causes outbreaks in humans as well, and is related back to consuming undercooked bear and walrus meat (4). While Parkinson (4) hypothesizes that loss of sea ice has changed the habitat, breeding and hunting grounds of marine mammals and altered transmission dynamics of zoonotic disease, empirical evidence linking both *Brucella* and *Trichinella* to climate change is lacking.

Vector-Borne Disease

Perhaps the best understood group of climate-sensitive diseases is vector-borne illnesses, diseases that are transmitted to humans via an arthropod vector. The three main mechanisms through which vector-borne diseases have been influenced by climate change are (1):

i. The changing geographic range, distribution and density of disease vectors, hosts and reservoirs.

ii. Increased survival and reproduction of pathogens, vectors and reservoirs.

iii. A rise in biting rates of vectors and/or more infected vectors driving up the transmission probability of disease.

The impact of climate change on vector-borne diseases is a function of other factors as well, including land use, urban development, behavioural practices such as use of insect repellent and personal protective equipment (PPE), population growth and density and health infrastructure (4).

The expansion in range of vectors, hosts and reservoirs is linked to increasing temperatures. Temperature is the environmental determinant that limits the northernmost range of vectors such as *Borrelia burgdorferi*, the tick that carries Lyme-disease causing pathogen *Ixodes scapularis* (8), and West Nile virus, carried in Canada mostly by the *Culex* genus of mosquitoes (10). Ogden et al. (15) created risk maps that predict the expansion of *I. scapularis* in the future with a changing climate and modelled that under a “slow” greenhouse gas emissions scenario, *I.*

scapularis populations will not pose a risk to Arctic regions. However, in a "fast" emissions scenario, some regions of the south Arctic will be at moderate risk for established populations of *I. scapularis* by 2080, particularly the region of Nunatsiavut (15).

Hoover & Barker (10) quantified the risk of West Nile virus (WNV) in circumpolar regions until the end of the century (10). They estimated that the threshold for WNV replication was 14.3°C, a temperature that the Canadian North is expected to experience with rapidly warming temperatures. Hoover & Barker (10) found that risk of sustained transmission would remain unlikely by 2070 in Arctic regions. The authors concluded that overall, short summers for virus reproduction and amplification, low temperatures in the Arctic and a lack of the *Culex* vectors generally put the Arctic at low risk for sustained WNV transmission. They did, however, note that if anthropogenic factors coalesce and magnify the implications of climate change, there may be high risk of WNV transmission in the Arctic in the future (10).

A review of the evidence found that risk of climate-sensitive infectious disease in the Canadian occurred across four main groups: waterborne, foodborne, zoonotic and vector-borne diseases. This evidence review also found that infectious diseases do not belong to just one domain or group. There is a dynamic interplay of infectious diseases and their risk factors, intensified by climate change and also exacerbated by the close connection with the land of indigenous populations in the Canadian North. For example, beavers are the hosts for the *Giardia* parasite (14). The beaver population has been determined to be increasing and expanding their range northwards, spreading the *Giardia* parasite. *Giardia* is a pathogen responsible for water-borne disease outbreaks, and water-borne illnesses are predicted to occur where untreated surface water is consumed (6).

There were several limitations to this review. Overall, there was a dearth of literature investigating this environmental health issue. While much of the literature seemed to suggest that there were potential risks and associations between climate change and infectious disease, this was not often supported by empirical evidence. Limited studies specifically investigate infectious disease risk specifically in the Canadian North, where indigenous populations have distinctive vulnerabilities and face unique challenges. Additionally, this review was limited in scope to capture only peer-reviewed literature and as such is not representative of the full breadth of knowledge around this issue. There were also strengths to this review, namely that the evidence used was high-quality peer-reviewed literature.

Conclusion

Climate change poses risks for increased incidence of waterborne, foodborne, zoonotic, vector-borne infectious diseases in the Canadian North. This population is particularly vulnerable due to the severity of climate change in the region, the close connection of the indigenous population to the land and the already poor health status and social conditions of the communities in the Canadian North. An evidence review was conducted and found that although transmission pathways exist for infectious disease, there was limited empirical evidence to inform quantification of risk, particularly foodborne and zoonotic diseases. The lack of syndromic and disease surveillance systems, coupled with incomplete local scale climate (long-term) and weather (short-term) observations makes it difficult to compute current and predict future risk. There is especially a lack of longitudinal studies that explore the association of climate with infectious disease, as most of the literature was ecological or anecdotal. Surveillance around climate change and infectious disease should be strengthened to improve climate-sensitive infectious diseases and climate data.

There was some evidence that waterborne illness was associated with higher risk of gastroenteric illness, and that vector-borne disease posed some risk to populations in the Canadian North. Risk factors for waterborne, foodborne, zoonotic and vector-borne diseases interact and are amplified by the close connection to the land of indigenous peoples. Consulting with indigenous peoples in order to come up with culturally appropriate and community-driven adaptation and mitigation initiatives is a necessary approach to tackle climate change and infectious disease risk in the Canadian North.

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Appendix

Search Strategy

MEDLINE

MeSH terms: Inuits, Arctic Regions, Health Services (Indigenous), Communicable Diseases, Climate, Climate Change, Temperature

Keywords: circumpolar.mp., arctic.mp., indigenous.mp., infectious disease*.mp., climate change*.mp.

Boolean Logic: (Inuits OR Arctic Region OR Health Services (Indigenous) OR indigenous.mp. OR circumpolar.mp. OR arctic.mp.) AND (Communicable Diseases OR infectious disease*.mp.) AND (Climate OR Climate Change OR Temperature OR climate change*.mp.)

Limits Applied: English Language and Year = 2006 to Current

Refinement and limits: These limits were applied to eliminate articles in languages other than English. The body of knowledge on climate change and knowledge of infectious disease risk in the Arctic is constantly being refined. Limiting the articles to 2006 ensures that articles were recent enough to be relevant in the present day.

Summary of Results: The total number of hits obtained was 27. With the English language limit and restriction to articles newer than 2006, this number came down to 21 results.

EMBASE

Thesaurus terms: Inuit, Arctic, Eskimo, Communicable Disease, Arctic Climate, Climate, Climate Change

Keywords: circumpolar.mp., indigenous.mp., infectious disease*.mp., climate change*.mp.

Boolean Logic: (Inuit OR Arctic OR Eskimo OR circumpolar.mp. OR indigenous.mp.) AND (Communicable Disease OR infectious disease*.mp.) AND (Arctic Climate OR Climate OR Climate Change OR climate change*.mp.)

Limits Applied: English language and Publication year 2006 to Present

Refinement and limits: See reasoning as applied to MEDLINE search above.

Summary of Results: The total number of hits obtained was 22. With the English language limit and restriction to articles newer than 2006, this number came down to 18 results.

Scopus

Title, Abstract and Keywords: Arctic, Indigenous, circumpolar, (infectious disease*), (communicable disease*), climate, (climate change*), temperature

Boolean Logic: (Arctic OR Indigenous OR circumpolar) AND (infectious disease* OR communicable disease*) AND (climate OR climate change* OR temperature).

Limits Applied: English language and Years 2006 to 2016.

Refinement and limits: See reasoning as applied to MEDLINE search above.

Summary of Results: The total number of hits obtained was 91. With the English language limit and restriction to articles newer than 2006, this number came down to 69 results.