Climate change and control of diarrhoeal diseases in South Africa: Priorities for action

Connections between temperature and diarrhoeal disease

Weather conditions, especially temperature and precipitation, play a critical role in shaping patterns of diarrhoeal diseases. They determine the frequency of outbreaks, and the spatial and seasonal distribution of cases. Not surprisingly, it is anticipated that the burden of diarrhoeal diseases will escalate with climate change, in tandem with gradual increments in mean temperatures, but also during episodic heatwaves. The degree and nature of this escalation will, however, vary with the mix of pathogens in an area, the quality of sanitation services, food hygiene regulations and their enforcement, and the age structure of the population, among other factors. Understanding these patterns can inform the design of measures to prevent and control heat-related diarrhoea. In this editorial, we sum evidence on the heat sensitivity of enteric infections in South Africa (SA) and other parts of sub-Saharan Africa (19 studies), drawing on articles located in a systematic review (methods detailed in Manyuchi *et al.*[1]), and consider the implications of these findings for control of diarrhoea in SA in the context of climate change.

Several mechanisms underlie the heat sensitivity of microbes. The reproduction, growth and survival rates of most microbes rise with temperature, within certain limits. Higher ambient temperatures accelerate contamination of food across the whole food chain, from preparation, processing and storage to eventual consumption. Importantly, on hot days people spend more time outdoors, and may eat food that is unrefrigerated and is raw or cold, rather than served cooked and hot.[2] Being outdoors also raises exposure to pathogens carried by birds, and farm and wild animals. Rural areas, *per se*, may be especially susceptible to heat-related impacts on diarrhoea.[3] Further, dust storms, especially frequent on hot and dry days, may settle dust particles with microbial contaminants onto vegetables and other fresh produce. Importantly, if power blackouts occur during hot weather – as we are currently seeing in SA and Venezuela – the integrity of food chains can be compromised, increasing risks of contamination.

While 15 of the 19 papers identified in the review reported strong connections between heat exposure and cases of diarrhoea,[3-17] 4 found negligible or even negative associations.[18-21] This inconsistency illustrates the complexity of pathways between temperature and infectious diseases. Indeed, these correlations are seldom linear and more frequently take an inverted U-shape, where diarrhoea rates rise with temperature, plateau and then decline. Relationships may also be J-shaped, where the incidence of diarrhoea remains stable below a certain temperature threshold, beyond which there is a rapid incline. Moreover, many enteric infections have seasonal patterns: rotavirus cases, for instance, classically occur in winter and campylobacteriosis peaks in spring.[18-20]

Seasonal patterns are not solely related to climatic factors, however, and are generally poorly understood. The complexity of transmission dynamics also means that many pathogens are both food- and waterborne, with temperature influencing both modes of transmission. On the plus side, the complexity of these connections means that there are multiple potential points of intervention.

Patterns of heat sensitivity of enteric infections in sub-Saharan Africa

During periods that are hot and dry, any additional increments in temperature appear to have especially marked impacts on the incidence of diarrhoea in sub-Saharan Africa.[4,8] This is concerning, as periods of hot and dry weather may lengthen and warm further with climate change, and cover ever-larger geographical areas. A study among children aged under 5 in Cape Town, SA, during the hot, dry months of the year, for example, found that a 5°C rise in temperature increased cases of diarrhoea by 40% 1 week later.[8] Similar effect sizes were noted in a study in Northern Ghana, at a 2-week lag,[12] and in Limpopo Province, SA.[15] In a study in Mozambique, the incidence of diarrhoea rose by 3.6% per 1°C increase in temperature.[6] Another study, however, using data from demographic health surveys across sub-Saharan Africa, found only weak associations between temperature and cases of diarrhoea in children.[21] Additionally, rotavirus occurrence was associated with lower temperatures in several studies, as shown elsewhere.[18-20]

Risks of cholera outbreaks are clearly raised by flooding, and interruptions and breakdowns in water and sanitation services, as is presently unfolding in the neighbouring countries of South Africa following Cyclone Idai, but can also be raised during periods of warm weather.[14,16,18] For example, a study in Zambia found that a 1°C rise in temperature 6 weeks before the onset of a cholera outbreak explained 5.2% of the increase in number of cholera cases.[5] The authors of a Tanzanian study reported that an increase of 1°C would raise cholera cases by 29%, considerably more than estimates in studies elsewhere.[13]

Sea surface temperature appears to predict cholera outbreaks on the subcontinent.[7,9,10,17] The incidence of cholera rose in a linear fashion with sea surface temperature in the KwaZulu-Natal outbreak in 2000.[7] High sea surface temperatures raise risks of heavy precipitation associated with cholera outbreaks,[11] but also enhance phytoplankton growth, leading to higher numbers of copepod zooplankton (small crustaceans commensal to cholera) that feed on these organisms. Cholera infections then occur after people drink untreated water with even a few cholera-containing copepods.

Implications for control of diarrhoea in SA in the era of climate change

Broadly speaking, there are two approaches to controlling heat-related diarrhoea. The first entails reducing pathogen concentrations in food chains, water sources and the community in general.[22,23] This approach attenuates the effects of temperature on diarrhoeal infections, potentially counterbalancing the impacts of climate change on case burden. The second approach involves outbreak preparedness, early-warning systems and heat-health action plans, where a specific set of actions are triggered at prespecified temperature thresholds.

Information about the lag time between periods of extreme heat and increases in cases of diarrhoea (1 - 6 weeks in the studies reviewed) can provide warning about outbreaks and facilitate their early detection, a central pillar of diarrhoea control. In the absence of forecasting and early detection, many unplanned admissions may occur, in under-prepared services, and with high morbidity and mortality rates. Lag periods vary considerably, however, contingent on the incubation periods of the pathogen(s) involved, and where and when food contamination occurred. Shorter lags point to heat-related contamination closer to the time of food consumption, while longer lags indicate exposure at the production and processing stages. Longer lags may also suggest that heat pathways involve an additional step of mechanical vectors, such as flies, which are mostly thermophilic.[4]

The recent floods in southern Africa following Cyclone Idai may suggest gaps in preparedness for extreme weather events, at national, regional and international levels. In Mozambique, a cholera outbreak began 2 weeks after the cyclone and oral cholera vaccination was initiated 1 week thereafter, in a large campaign involving almost 1 million doses.[24] It is worth considering whether global stockpiles of the vaccine could have been mobilised earlier, however, based on the expected lags and given the fact that a cholera outbreak occurred in 2018, suggesting favourable conditions for cholera transmission, even pre-cyclone.[25] Experiences with the listeriosis outbreak in SA in 2017/18 indicate that deficiencies in preparedness and outbreak control are not restricted to the neighbouring countries: it took 14 months to identify the outbreak source, and there were substantial gaps in the case histories of affected patients, for example.[26,27]

Although heat sensitivity and related causal pathways vary considerably between pathogens and settings, heat-health action plans can set out graded actions, where sets of preventive and control measures are implemented at different temperature thresholds. These actions include rapidly sharing information with health professionals and the public on levels of risk; promoting food safety and safe water use; making provision for additional case burdens in health services; shifting from surveillance of all-cause diarrhoea to making specific pathogen diagnoses; and specific measures such as cholera vaccination.[23]

Conclusions

Average temperatures in SA are anticipated to escalate by 2 - 4°C in the forthcoming decades.[28] Risks of cholera and other outbreaks clearly increase during disasters, but now also need to be recognised as important phenomena during heatwaves and the increasingly high temperatures that characterise climate change. The overall burden of diarrhoeal diseases may therefore increase considerably, especially among lower socioeconomic groups and children. Understanding these impacts can help delineate high- and low-risk periods, provide insights into the epidemiology of enteric diseases in the country, identify remedial actions, and help prioritise diarrhoeal diseases in heat-health action plans. Developing and adequately resourcing such plans, which encompass disaster preparedness, should form a key part of SA's climate change response in the coming years.

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