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How Climate Change May Threaten Progress in Neonatal Health in the African Region

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Abstract
Climate change is likely to have wide-ranging impacts on maternal and neonatal health in Africa. Populations in low-resource settings already experience adverse impacts from weather extremes, a high burden of disease from environmental exposures, and limited access to high-quality clinical care. Climate change is already increasing local temperatures. Neonates are at high risk of heat stress and dehydration due to their unique metabolism, physiology, growth, and developmental characteristics. Infants in low-income settings may have little protection against extreme heat due to housing design and limited access to affordable space cooling. Climate change may increase risks to neonatal health from weather disasters, decreasing food security, and facilitating infectious disease transmission. Effective interventions to reduce risks from the heat include health education on heat risks for mothers, caregivers, and clinicians; nature-based solutions to reduce urban heat islands; space cooling in health facilities; and equitable improvements in housing quality and food systems. Reductions in greenhouse gas emissions are essential to reduce the long-term impacts of climate change that will further undermine global health strategies to reduce neonatal mortality.

Introduction

The world's climate is warming with increasing intensity. The IPCC estimates that "Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide and other greenhouse gas emissions occur in the coming decades" [1]. Although there is an emerging interest in climate effects on human health, public health policy has not sufficiently addressed the risks of heat and other climate risks for neonates (the first 28 days of life), infants, and children.

Africa is likely to be one of the regions most affected by climate change [1], which will increase the frequency and intensity of heat extremes, heavy precipitation, agricultural droughts, and the proportion of intense tropical cyclones. African countries currently experience a high

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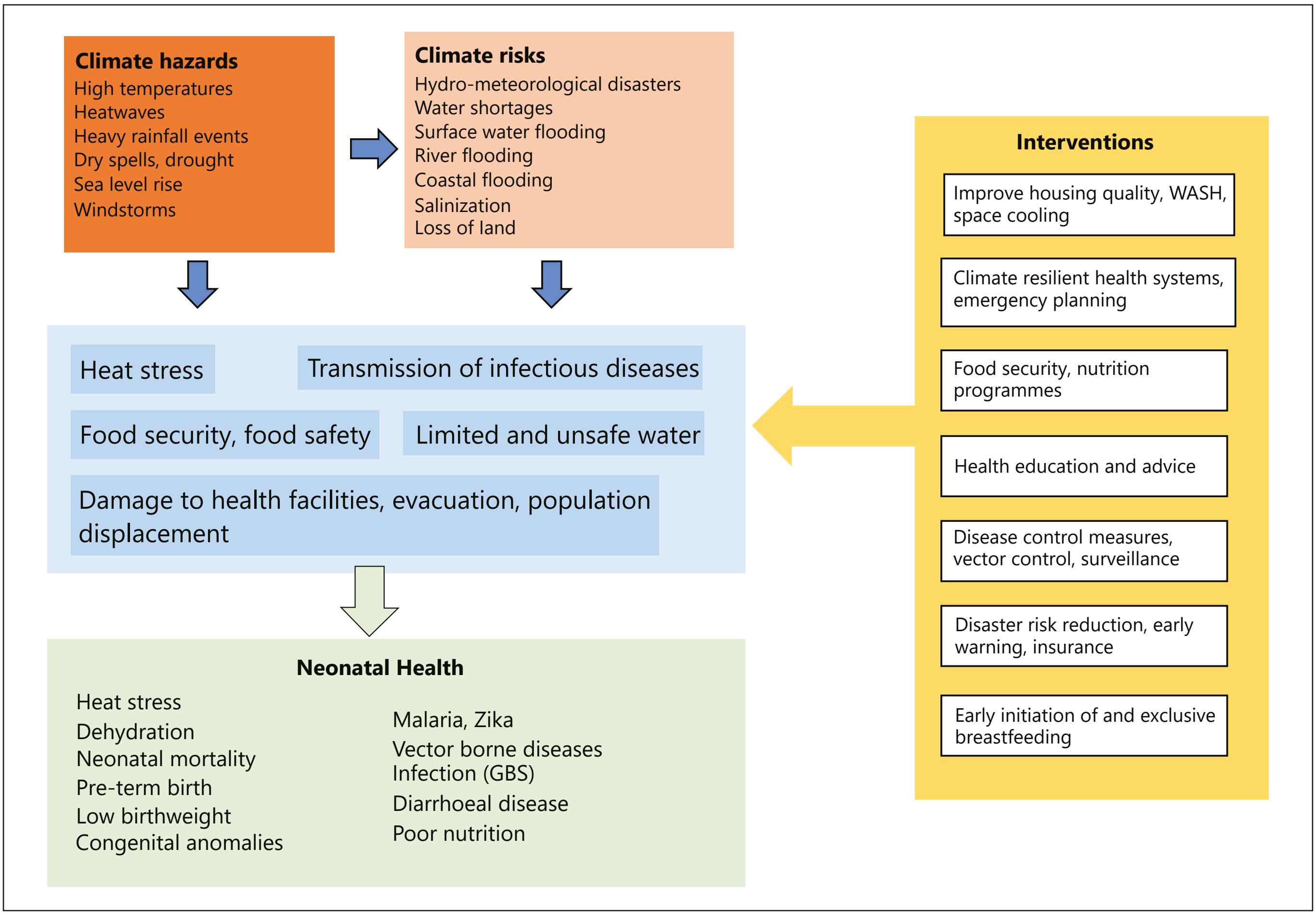

Fig. 1. Pathways in which climate change may affect neonatal health and interventions that may reduce the health risk.

burden of neonatal mortality. The incidence of preterm birth and low birth weight is high compared to other regions, and many pregnant women may have compromised health when entering pregnancy. Three-quarters of all neonatal deaths, globally and in Africa, are in the first week of life, and many deaths occur at home without contact with the formal health sector. Thus, many neonatal deaths remain unrecorded, and the lack of routine and robust mortality data has been a barrier to understanding the environmental determinants of neonatal mortality.

Figure 1 describes the pathways in which climate change may affect neonatal health, through increases in daily temperatures and changed rainfall patterns. Babies born too soon, with low birth weight and an immature immune system, are already at high risk of adverse outcomes. This paper reviews the evidence regarding the impacts of climate hazards on neonates and then discusses potential interventions to address these challenges. We do not discuss air quality in detail because it is not one of the main pathways by which climate change affects health. Fossil fuel combustion causes both air pollution and climate change; therefore, actions to reduce carbon emissions will also significantly benefit infant health through improvements in air quality. Climate change, environmental degradation, conflict, pervasive inequalities, and predatory commercial practices threaten the health and future of children in every country [2].

Heat Stress in the Neonate and Infant

Heat triggers several pathophysiological processes that manifest as clinical symptoms and signs in foetuses and neonates. These include increased foetal tachycardia and reduced foetal movements [3], and foetal distress [4]. Clinical manifestations of heat stress in the neonate include meconium aspiration syndrome [4], neonatal jaundice [5], heat exhaustion and neurological dysfunction, and dehydration [6], leading to emergency hospital admission, long-term sequelae, or death.

Many households in Africa currently experience very high temperatures and high humidity which present a risk to health for adults and children. Neonates and infants are less able to dissipate heat and thermoregulate [7], and high humidity limits the ability to lose heat through sweating. Overbundling in clothing or blankets and being placed in direct sun without shading can also contribute to hyperthermia in this age group [6, 8]. Critical heat illness and dehydration may further be accompanied by electrolyte disturbances, peripheral gangrene, convulsions, central venous and aortic thrombosis, and coma in the acute period. The fatality rate of heatstroke is high. Hepatocellular necrosis and disseminated intravascular coagulation are reported in children with hyperthermia, with postmortem findings of intrathoracic petechiae [9].

Increased mortality among neonates due to heat stress has been reported during heatwave events [10]. Analysis of US deaths attributed to excessive heat shows that risk increases at the very young and very old end of the age spectrum. The risk of heat death (ICD10 X30 and T67) is 4.4 times higher in infants than in young adults [11]. Mortality from nonhyperthermia causes can also increase during hot weather. A study in rural Bangladesh has shown that neonates delivered during periods of extreme heat and at home are more likely to be severely ill than those born on cooler days [12]. We found no studies that quantified the association between daily temperature and perinatal mortality or morbidity. Several studies have shown an association between infant mortality and high daily temperatures (e.g., above 95th centile) [13, 14] and emergency child admissions and high daily temperatures [15, 16]. Further, there is good evidence that high temperatures affect birth outcomes, including the risk of preterm birth, low birth weight, and stillbirth [17].

The neonatal thermoregulatory capacity depends on several factors including environmental temperature, feeding, time of day, age, and growth rate [18]. The interactions between temperature and humidity and other environmental stressors (e.g., air pollution) are poorly understood. At high ambient temperatures, neonatal thermal equilibrium can only be achieved by additional heat loss through vasodilation and evaporation of sweat and not by downregulating basal metabolic rate. In small premature infants, the sensitivity of the thermoregulatory system may be especially vulnerable because of the larger body surface versus weight. The neonatal responses to overheating were studied in 83 healthy term and preterm infants who found that even the most immature babies appeared to make appropriate responses to moderate, but not extreme, heat stress [19]. When it is very hot, even small changes in body temperature can increase the risk of neonatal mortality [20]. Elevated core temperature may induce acute apneic episodes [21] and sudden death [22].

Hyperthermia may aggravate brain damage in neonatal hypoxemia-asphyxia cases as shown in experimental animals [23]. The literature on hyperthermia effects on human neonates with hypoxic-ischemic encephalopathy is scarce, while hypothermia is well documented as neuroprotective for the term and near-term infants with hypoxic-ischemic encephalopathy, by inhibiting various events in the cascade of injury resulting from excitotoxic and oxidative injury culminating in cell death [24, 25].

Neonates and infants depend on others to keep cool and hydrated, and to avoid heat-related complications [6]. However, during an extreme heat or drought event, mothers may become exhausted themselves which may impact the quality of the care they provide for their newborns. Most babies, regardless of gestational age and illness, are less active in the heat. Warning signs of neonatal overheating include a flushed face, warm skin, rapid breathing, and heart rate, sometimes restlessness and irritability, but the baby may not develop a fever or sweat. The physical response to heat stress may be difficult to clinically distinguish from the diversity of neonatal and infant illnesses. Importantly, the baby may become silent, which may be misinterpreted as a healthy sleeping baby, and not offered fluids and breast milk until it is too late and already severely dehydrated.

Climate Impacts on Nutrition and Breastfeeding

Climate change is likely to adversely affect food security with implications for maternal health, babies, and infants [26]. Climate change is projected to cause significant reductions in food availability, which can be exacerbated by increases in extreme weather events [1, 2].

Early initiation of breastfeeding and exclusive breastfeeding is essential for child health. The effective establishment of lactation requires early and frequent breast stimulation and emptying of the breast to ensure enough milk for nutrition and hydration [27]. This mechanism helps avert infant dehydration and ensures and enhances nutrition. Breastfeeding women need to drink enough fluid to maintain breast milk production and avoid dehydration. Human milk provides all the necessary fluids that the exclusively breastfed neonate needs [28], with 90% water and other essential nutrients, and antimicrobial factors that may help reduce the risk of neonatal infections [29]. In vitro studies suggest that high temperatures (39°C) induce a high lactation capacity of mammary epithelial cells through control of STAT signalling, whereas long-term exposure to 41°C leads to a decline in milk production by inactivation of the signalling pathway as well as a decrease of the number of milk-producing cells [30].

Fluid intake is important for neonatal thermoregulatory function, with uncompensated loss of body fluid considered a major risk factor in the development of heat illness [8]. It is possible that dehydration is one of the main impacts of heat on neonates. However, there is very little evidence in the published literature on the role of high temperatures in neonatal admissions for hyperthermia or dehydration.

Danger signs of dehydration include a neonate that looks unwell and restless, is refusing to breastfeed, have no or fewer wet nappies. During periods of heat, babies may not want to feed often or for long. This may be uncomfortable for mothers who are also suffering from heat stress. The discrepancy between the nutritional demands of the newborn and the nutritional supplies is particularly evident in the first weeks after birth [31]. Malnutrition is a risk factor for other diseases, and those born too soon or with low birth weight are especially vulnerable to adverse effects on the metabolism needed to enable growth and development.

Heat episodes can also be associated with hydrological or agricultural drought leading to reduced agricultural yields and increased household food insecurity. Reductions in water quality and quantity are a risk to maternal and neonatal health, including infant morbidity, diarrhoeal disease, and infections in particular [28, 32]. The hydrating properties of breast milk are sufficient in exclusively breastfed infants under hot and arid conditions [28], and consequently, there is no robust evidence that there is a need to supplement newborns with water or herbal teas to prevent dehydration except under some conditions [33]. Climate change may however increase the risk of dehydration in mothers, where there are high temperatures and limited access to household water.

Climate-Sensitive Infections

Changes in temperature, rainfall, and humidity influence the transmission of infectious diseases [2]. Increasing temperature is known to affect the growth of bacteria in the environment. High ambient temperatures and high humidity were associated with increased Group B strep colonization during pregnancy in Spain [34], relevant to neonatal health since Group B strep-invasive disease is often fatal. Neonatal-invasive infections develop rapidly and are frequently fatal. It has been suggested that an increase in local minimum temperatures may facilitate antibiotic resistance to common neonatal pathogens [35]. Further, there is some evidence that higher temperatures may increase the risk of infection due to effects on adaptive immunity by promoting activation, function, and delivery of immune cells [36].

Changes in temperature, rainfall, and humidity influence the transmission of vector-borne diseases [37] and climate change is likely to expand the range and transmission seasons for a range of diseases important for maternal and neonatal health [38]. The distribution, intensity of transmission, and seasonality of malaria have already been affected by higher temperatures and increased vector activity [39]. Neonatal and congenital malaria are potentially life-threatening conditions. Recent reports suggest that the number of cases is increasing, but the epidemiology remains poorly described. There is a need to conduct routine malaria diagnostic testing for febrile neonates in malaria-endemic areas [40].

Mosquito-borne arboviruses are likely to expand their distribution due to climate change. Neonatal dengue is reported in the literature with contradictory findings on clinical characteristics and diagnosis [38]. Zika virus infection during pregnancy can cause infants to be born with microcephaly and other congenital malformations. Climate change will facilitate the spread of invasive mosquitoes, including the vectors of dengue and Zika viruses [41].

Climate-Resilient Health Systems: Health Workers and Health Facilities

Heatwaves can cause problems with health service delivery as they affect the functionality of hospitals and the thermal comfort of patients and clinical and other staff. Reported impacts of heatwaves include discomfort or distress of mothers and their visitors; equipment failure, such as failure of refrigeration systems, disruption of laboratory services; and degradation or loss of medicines. Power failures are more likely to occur during heat events due to surges in electricity demand. Health facilities could make better use of climate services (including heatwave alerts and daily weather forecasts) to improve planning.

The WHO has developed a framework for climate-resilient health systems [42], which includes consideration of health facilities, health workforce, and climate-informed health programmes. The criteria for climate-resilient facilities, including ensuring facilities, have a reliable energy system. A resilient healthcare facility is structurally and functionally able to withstand climate hazards and therefore long-term planning is required to ensure the health facilities are designed to function well in future hotter climates. Health facilities should be able to cope with acute increases in demand (e.g., increased NICU admissions in a heatwave) as well as provide space for cooling in maternity wards and delivery rooms.

Urban areas are often hotter than surrounding areas due to less vegetation and more heat-absorbing surfaces that retain and subsequently reradiate incident solar radiation (the urban "heat island" effect). A study in health facilities in urban Ghana [43] found that some health facilities were 6°C warmer at night than reported by official records from nearby weather stations, due to a combination of the greater thermal inertia of the buildings and the urban heat island effect. Staff in the health facilities made operational adjustments to reduce extreme weather stress, including improving ventilation during extreme heat, and using alternative power sources for emergency surgery and storage during outages. The study highlighted the need for routine temperature monitoring to better manage heat in health facilities and improved emergency response plans.

Interventions and Response Measures for Mothers

Cost-effective interventions can reduce the health risk of elevated ambient temperatures, including space cooling, enough breastfeeding for hydration and nutrition of babies, and guidance for care to reduce the risk of negative effects of extreme heat. Heatstroke or heat illness can be managed through early resuscitation and cooling. Neonatal overheating, dehydration, and malnutrition caused by heat are probably associated with first-time motherhood, early postdelivery discharge, maternal illness, inadequate lactation support for mothers, and undiscovered neonatal illness, so it is important to inform mothers and caregivers on the danger signs of heat illness and guide them to close observation, maybe through public health information campaigns.

Kangaroo mother care including skin-to-skin is protective against a wide variety of adverse neonatal outcomes, facilitates close observation of the baby, and also improves the likelihood of exclusive breastfeeding [44]. This safe and low-cost intervention has the potential to prevent many complications associated with preterm birth and may also provide benefits to full-term neonates. However, in the heat, mothers may be reluctant to practice skin-to-skin care due to discomfort for mother and baby. The benefits and effectiveness of kangaroo mother care in very hot settings need further research.

The healthcare giver and mother need to be aware of danger signs of hyperthermia and dehydration. There is a need for additional research to improve our understanding of how weather and climate can influence neonatal health. Filling gaps will help better define the potential health impacts of climate change and identify specific public health adaptations to increase resilience. Thus, region-specific policies are vital to the mitigation of heat-related deaths [10]. Given the scarce evidence on the effectiveness of the above interventions, further implementation research is needed on behaviour and possible adaptation in very hot settings.

Breastfeeding Interventions

Whenever possible, exclusive human breast milk is the optimal choice for neonates and infants. To ensure adequate volumes, it is important to support the mother to start breastfeeding or expressing breast milk early and do it regularly [45]. Guidance and support for breastfeeding and management of cooling the neonate could be updated to address concerns about dehydration and heat stress. There is good evidence that educational programs help promote sustained breastfeeding [46] and should incorporate the involvement of partners and fathers, as well as health systems, households, and the community [47].

Improved guidance for health workers should include knowledge to assure survival from potentially fatal heat illness. Guidance should be to quickly and appropriately recognize and treat the neonate at risk, before collapse. Management protocols should establish effective prevention and management strategies to minimize the risk of and improve the outcome from dehydration and heat illness, thereby affecting neonatal and infant health via policy creation and modification.

Training instructors to teach mothers and families on how to observe danger signs and how to manage heat and its complications should begin at the start of each hot season. Training opportunities online and in-person should be available for information and training for healthcare workers who meet the families during antenatal visits and also when the baby is newly born. A variety of Internet-based e-technologies can be used to promote, educate, and support care by healthcare givers, mothers, and families. Staff at local health centres in rural districts where babies are born at home should be trained and involved in planning to understand danger signs.

Housing Design and Shading Interventions

There are many factors in poor urban designs that can increase temperatures within cities (urban heat islands), and this may exacerbate temperatures in rapidly growing cities. As urbanization increases, planning should aim to build well-designed dwellings and maintain or increase urban green space and other measures to reduce high indoor temperatures. Understanding how housing quality influences neonatal health, especially in hot low-resourced settings, is important. In many parts of Africa, people live in small, poorly ventilated houses without windows and with roofs made of heat-trapping materials. Several aspects of the indoor environment can negatively affect neonatal health. Cooking is often done inside houses using fires, producing large volumes of smoke that remain trapped inside. These houses may experience indoor temperatures as high or higher than outdoor temperatures and do not protect the neonate against overheating. Teare et al. [48] found that some low-cost dwellings experienced 4°C higher temperatures indoors than outdoors. There is considerable evidence regarding the adaptation of housing designs, including traditional designs, which could reduce the risk of high indoor temperatures [48]. Adapting building materials to counteract rising ambient temperatures is important, for example, the use of cement floors which are cooler than other floor types. Houses can lack reliable electricity, and in some areas and during droughts, there can be shortages of water. Use of renewable energy to ensure reliable electricity will help efforts to reduce the indoor temperature, for example, by the use of fans (although these tend to be less effective at high temperatures), or the production of ice packs or cold water.

Conclusion

There is emerging evidence that newborns are at risk from extreme hot weather, flooding, and storms. More research is needed to explore the mechanisms by which heat affects neonatal health and establish which neonates are most at risk. Cost-effective interventions can be developed to reduce the risk of heat, but there is a need for more evidence-based interventions, including how to detect the early signs of heat stress in neonates and infants. In addition, more evidence is needed on how other weather extremes affect the health of neonates in Africa, including through damage caused to the health structure.

Long-term planning is required to ensure that health facilities are designed to function well in future hotter climates. Vulnerability to high temperatures is exacerbated by poor building designs and inappropriate building materials, and lack of access to reliable energy supply. Potential interventions include changes to health facility design, planting trees for shade, cooling interventions, and revised health guidance that include close observation of the neonate, adequate hydration, and prevention of infections. Additional research is needed to develop these interventions and support countries in Africa to prepare and adapt to rising regional temperatures.

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Conflict of Interest Statement

Matthew F. Chersich holds investments in the fossil fuel industry through his pension fund as per policies of the Wits Health Consortium. The University of Witwatersrand holds investments in the fossil fuel industry through its endowment and other financial reserves. The other authors have no conflicts of interest to declare.

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Author Contributions

Britt Nakstad drafted and finalized the manuscript. Veronique Filippi, Adelaide Lusambili, Nathalie Roos, Fiona Scorgie, Matthew F. Chersich, Stanley Luchters, and especially Sari Kovats gave substantial contributions to the conception and design of the work, as well as acquisition, analysis, or interpretation of papers in the work; and critically revised it for important intellectual content and gave final approval of the version to be published. Britt Nakstad, Veronique Filippi, Adelaide Lusambili, Nathalie Roos, Fiona Scorgie, Matthew F. Chersich, Stanley Luchters, and Sari Kovats agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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