

Climate change, direct heat exposure, health and well-being in low and middle-income countries

Climate change and health has been given increasing attention during recent years, largely initiated and triggered by the insightful report by McMichael and colleagues published a decade ago (1). Until then research on, and analysis of, the impacts of climate change had focussed on environmental change and impacts on ecosystems. Further review of the health aspects (2–4) and assessment of the contribution of climate change to the global burden of disease (5) has led to a greater understanding of the importance of this issue and the latest report from the Intergovernmental Panel on Climate Change (IPCC) (6) includes a 40-page chapter on ‘Human health’. However, very sparse attention is paid to the non-fatal effects of direct heat exposure.

It seems logical that an analysis of the impacts of climate change on human health should start with a thorough review of what we know about the *direct impacts of climate on health*. The most obvious climate variables that people would be aware of are: air temperature, air humidity, rainfall, wind speed and wind direction. In addition, a meteorologist could add cloud cover, solar radiation intensity, air pressure and other more specialised variables. Several of these variables link to human health via the basic physiological mechanisms that balance core body temperature at approximately 37°C in all human beings (7). A very small range of temperatures around this value is concomitant to maintaining good health. Serious heat stroke and even death occurs after a relatively short time if core body temperature goes above 42°C (7).

Additional mortality due to increased exposure to heat because of climate change has been studied and reviewed in a number of reports (8), and is also given substantial attention in the IPCC report (6). However, the non-fatal impacts on health and well-being may be even more important. If core body temperature exceeds 38°C over several hours, heat exhaustion and reduced psychometric and motor capacity will occur. Above 39°C, more serious heat stroke and unconsciousness may occur. Because individual variation is considerable, heat exposures and possible effects need to be monitored when work is carried out in hot environments in order to protect more sensitive people (7). As examples of the most

serious effects that can occur among working people, some information about the situation in a South African gold mine in the 1950s is presented in Table 1.

The heat transfer between the human body and the environment depends on climate and clothing. If air temperatures exceed 35°C, the human body can only maintain normal core body temperature by the heat-reducing mechanism of sweat evaporation (9). This mechanism is strongly influenced by air humidity, wind speed and clothing. In certain climatic conditions, even if very light clothing is worn, sweat evaporation is not sufficient to maintain core body temperature and a health-threatening increase in core body temperature will occur. Internal heat production in the body also greatly influences the need for sweat evaporation cooling. At rest, this heat production is low, but for people working or engaging in heavy physical activities in hot environments, the internal heat production becomes a major challenge for the maintenance of body heat balance (7).

Thus, one can easily imagine the situation for workers carrying out heavy labour in tropical countries where both air temperature and humidity are high, particularly during the hottest seasons. Heavy labour is common in agriculture, construction and manufacturing industries without air-conditioning, and is also a feature of the daily chores of poor people, e.g. during subsistence agricultural work, crowded cottage industry work and collection of drinking water or fire-wood. This aspect of climate change and health has not been fully analysed, even though the physiological mechanisms have been known for decades and the relevance of climate change for workers’ health was highlighted 10 years ago in a conference paper by Kjellstrom (10). Examples of how heat exposure during work currently affects people in low and middle-income countries (Table 1) show how serious the health impacts may be and how worker productivity is reduced among those who manage to avoid serious heat stroke. Climate change will require additional interventions to avoid heat stroke and to compensate for reduced productivity.

In order to quantify the health and well-being impact of heat exposure, different heat stress indices have been developed (7). Some of them are based on ‘comfort’

Table 1. Examples of heat and productivity suppression in different parts of the world

Geographic location and work activity; source of information, references	Heat and productivity effects
1. South African gold mine with >200,000 underground miners, who worked in extremely hot and humid conditions; 1956–1961 (11)	About 3.3 deaths/1,000 miners/year due to fatal heat stroke when wet bulb temperature (Twb) exceeded 34°C; 0.7 deaths/year/1,000 miners when Twb was between 31 and 33°C. Acclimatisation to heat before going underground reduced the risk, but even after acclimatisation two-thirds of new recruits were not able to carry out heavy labour in the hot work environment. Work intensity needs to be closely monitored by ‘boss-boys’ to detect early symptoms of heat stroke and force rest as required.
2. Agricultural workers in El Salvador and Nicaragua cutting sugar cane with a machete in the sun for 6–8 hours each day during a 3–5 month harvest; 2000–2008 (12, 13)	Young sugar cane workers have a very high rate of serious chronic kidney disease, which is often fatal. Daily dehydration due to heat and sweating, and without sufficient drinking water supply in the farm fields is a likely contributing cause, but other causes are being investigated. However, diabetes and hypertension cannot explain the high rates of this disease in this population. Sugar cane cutting cannot be carried out in the afternoons on sunny days due to excessive heat exposure, which reduces productivity.
3. South India assembly work in car and truck factories; 2008 (personal communication from company safety officers)	In these factories without air-conditioning, the air temperatures reach 42°C in the afternoons of the hottest months. The workers need frequent rest breaks to avoid heat stroke. At the car production line, this is achieved by employing two people to do one person’s job. In the truck factory, much fewer orders are put through to the factory floor in the hottest months. Heat protection of workers reduces productivity.
4. Northern Vietnam shoe factory with 2,900 young women workers; 2002 (personal communication from factory manager)	The daily production target is the same throughout the year. In the cool period the workers start at 07.30 and in the hot period at 06.30. In the hot period they get longer rest breaks (three per day), and the actual daily working hours are greater than in the cool period in order to meet the production target. The reduced productivity caused by heat is compensated for by the workers’ longer working hours (at the same daily pay).
5. Southern states of the USA; early 20th century (14)	Economic historians have reported on the lower productivity in the southern parts of the USA before air-conditioning was introduced in factory and office buildings. The culture of the South, with its hot and humid climate conditions, was different from the North, and work was carried out at a more leisurely pace. One major reason for this difference was the physiological needs to ‘slow down’, which in other hot places of the world is demonstrated by ‘siesta’ and a working hour distribution very different from nine to five.

variables and some on the physiological limits of the human body. The most widely used ‘heat stress index’ is the Wet Bulb Globe Temperature (WBGT) which is based on physiology and used in international and national occupational health guidelines (7). This index was developed by the US Army to protect trainee soldiers from dangerous heat stroke and integrates the heat

exposure impact of air temperature, humidity, wind speed and heat radiation.

An international standard (15) based on WBGT provides guidance on the work/rest ratios required to maintain core body temperature below 38°C under different heat exposures and work intensity conditions. The increasing need for rest at higher heat exposures will

reduce worker productivity and well-being incurring loss of income and experience of exhaustion (10). If the rest period needs are not taken into account, core body temperature will increase leading to the serious health risks associated with heat stroke. Ongoing and future climate change will lead to higher heat exposures for billions of people in tropical countries, and most likely affect poor people in labouring occupations particularly, adding to the health inequities caused by the other health hazards linked to climate change (5, 16).

Global Health Action has initiated the preparation of a series of papers on the health and well-being aspects of direct heat exposure in low and middle-income countries, to be published in the near future. The aim is to increase awareness of the non-fatal health-related impacts of heat exposure and the immediate need to develop and apply preventive interventions, particularly in tropical low and middle-income countries. Climate change will make the environment even hotter and long-term plans for ‘adaptation’ need to consider the health threats of increasing heat exposure.

Introductory papers describe the basic physiological mechanisms behind the ‘health and productivity suppression’ caused by heat exposure, the impact on ‘work ability’ from heat exhaustion, and the need to reduce work/rest ratios. Other papers will describe the current situation for workers in hot environments in different parts of the world, recorded health impacts and the potential for implementing better prevention programmes. In conclusion, there is a need for more field research that will allow better quantification of these effects and encourage the development and application of feasible preventive interventions to protect all those at risk.

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