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Perceptions of, and reactions to, environmental heat: a brief note on issues of concern in relation to occupational health

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Average temperatures around the world are already increasing, and climate change projections suggest that global mean temperatures will continue to rise. As the effects, and projected effects, of climate change are becoming clearer, it is more apparent that the health effects of heat exposure will need further investigation. The risks associated with heat exposure are especially relevant to understandings of occupational health for people involved in labouring or agricultural work in low-income countries. This review is a partial look at the ways in which issues surrounding heat exposure and occupational health have been treated in some of the available literature. This literature focuses on military-related medical understandings of heat exposure as well as heat exposure in working environments. The ways that these issues have been treated throughout the literature reflect the ways in which technologies of observation are intertwined with social attitudes. The effects of heat on the health of working people, as well as identification of risk groups, will require further research in order to promote prophylactic measures as well as to add to understandings of the actual and potential consequences of climatic change.

Keywords: *climate change*; *heat*; *heat stroke*; *occupational health*; *military*; *colonialism*

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As with any subject of research, a current understanding of heat and its effects on human health and well-being will be informed by analyses of ideas from the past (1). This work is part of a wider project looking at the health effects of heat exposure, with a focus on the effects on occupational health and productivity (2). A literature review forms an important part of this work as it highlights the position of this current research in a long history of concerns with heat. It draws attention to the continuity of ideas that feed into any study and illustrates the important part that our own political perspectives play when adding to this history of ideas. My own academic interests and background also shape the way that the historical framework of ideas is interpreted here. My work, then, stems from an interest in health from a perspective rooted in medical anthropology and occupational health as well as concern about global environmental change.

The focus of this literature review has mainly been on Euro-American understandings of heat from the late 19th century onwards and will, therefore, represent only a partial endeavour. This is particularly the case as the literature referred to here is notably always about someone else – from military surgeons writing about their officers to researchers writing about factory workers. The abundance of literature related to increasing temperatures and food security, heat and housing design, and rising temperatures and climate change will be analysed elsewhere. These omissions will inevitably affect the ability to represent the variety of health impacts of heat and will restrict our vision to the most direct exposure to heat at work. Search engines such as the American Meteorological Society Online Journals, JSTOR, and PubMed have been consulted using search words such as 'heat stress,' 'heat + health,' 'heat stroke,' 'heat waves,' 'temperature + health', etc 3. The Wellcome Trust medical history library in London, the British Library, and the London School of Economics' Government Collections have served as sources of some of the earlier literature.

The effects of heat on military personnel and working people are two of the major themes that characterise the literature relating to heat and the effects of high temperatures. The links between technoscientific understandings of the world and militarisation have been

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persistent (3) and the military concern with the effects of heat on the bodies of soldiers has long been a driving force behind the understanding of heat. Attempts to understand the effects of heat on workers and their work have also provided motivation to understand the health effects of heat exposure (4). A longitudinal view of understandings of heat exposure and heat stroke show a shift in scale, or epistemological level (5), from the identification of common symptoms to understandings of the physiological processes behind the pathogenesis of heat stroke (6).

As part of global climatic change, rising global mean temperatures are also predicted to increase the risk of heat stroke (6). Projecting future patterns of heat exposure is particularly complex as it is thought that the projected increases in mean temperatures will not occur as constant gradual changes (7) but will, instead, be experienced as increased frequency, duration, and intensity of hot spells (8). Increasing human heat exposure due to climate change causes risks to health, human performance, work productivity, and local economic development (2, 9). This aspect of climate change has received very little attention, and this paper will focus on heat-related risks as part of a history of the different approaches to heat and its effects on occupational health.

Results and discussion

Health impacts of heat in the military

Medical understandings of the health impacts of heat are not new. Heat-related injuries have received various names throughout medical history including 'heat spots', 'heat collapse', 'heat exhaustion', and 'heat cramps' (10) as well as 'sun stroke' and 'heat apoplexy' (11), 'thermal fever' (12), and 'heat pyrexia' (13). Understandings of the effects of extreme heat on the body are intertwined with militarism and imperialism. The limitations presented by heat stress on the activities of soldiers have been of interest across various military agencies for many years. This was a particular concern of those involved in the British military presence in its colonies in the latter half of the 19th century. During this time, the health of 'European' troops in the Indian heat of April and May was a concern that was to affect discussions surrounding military planning. In 1884 Major-General MacGregor, Quarter Master General in India, wrote of the 'risk incurred by the prolongation of the trooping season so far into the hot weather,' arguing that the last British vessel should leave India no later than the 1st of April (14). At this point in Britain's colonial project there was a general and relatively subjectively expressed concern about heat and heat stress. Changes in military approaches to dealing with the hot climate of India came after a sustained period in which little effort was spent on alterations of behaviour due to high temperatures. In 1904 Lieutenant-Colonel Giles reported that recent consideration of the climate was preceded by a period in which 'our great grandfathers (were) fighting or playing cricket in exactly the same costume as their contemporaries at home. No alteration whatever was made in the soldier's dress' (15).

In 1887 a British military surgeon described 'heat-stroke,' with a general focus on symptoms and post-mortem appearance (11). The symptoms were noted as 'flushed face, hot, dry, burning skin; if conscious, complaining of intense pain in the head; generally unconscious, pulse feeble, breathing shallow and laboured; at times comatose, with stertorous breathing, in others violent convulsions relapsing into coma' (11). Post-mortem appearance invariably showed subconjunctival ecchymosis (11) or the escape of blood into tissues just under the skin causing discolouration (10). Treatment included laying out the patient in the coolest place possible, emptying the lower bowel, the application of 'wet packs,' and the administration of calomel (11); a mercury-based compound that is no longer used (16). Otherwise, men of 'weakly constitution' should be sent to the river or be moved in an attempt to provide a 'change of air' (11).

The effects of high temperatures on the colonial British military would continue through the early 20th century and the British Library's India Office documents show many of the ways in which heat became important in this context. A draft letter of 1912 denies a Captain's wife's request for a 'compassionate allowance' after 'her husband has become insane after eight years of illness due to sunstroke while on duty at the range at Lahore' (17). This request was rejected on the basis that sunstroke could not be confirmed as the origin of the Captain's insanity and because there was some doubt as to whether sunstroke qualified for an injury pension. In 1916 a case was brought to the Court of Enquiry regarding 19 deaths as a result of heat stroke on a train carrying troops between Karachi and Rawal Pindi. It was found that 'only reasons of urgent military necessity could justify the movement of un-acclimatised British troops across the Sind Desert during the hot season' (18). These records show that heat and its effects on the well-being of military personnel was an issue at the turn of the century, and that the focus was on avoidance of extreme heat rather than on adaptation and coping strategies.

It is worth noting – to aid our understanding of military responses to heat – the general distaste of those writing about 'conditions' in tropical climes. The 'conditions' to be borne invariably included reference to the people inhabiting colonised countries. In his account of the 'Medical Arrangements during the Burma Rebellion of 1931,' Major-General West notes that, in efforts to preserve the health of the troops in the field, measures

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were taken to avoid the posts 'unfavourably situated' near 'crowds of native women and children' (19). The paternalistic racism and colonialist discourses, which characterise much of the military approach to health in tropical regions at this time, can be seen in assurances that 'it should be the duty of a civilised government to place at the disposal of the (Oriental) population every possible means of combating disease which our superior knowledge and civilisation enables us to recommend' (15). It is noted that on one occasion difficulties 'obtaining sufficient coolies' to carry heavy loads put soldiers at increased risk of heat-related hyperpyrexia (13). These concerns remind us that although technologies of observation and the construction of expert knowledge have been presented as the 'objective' grounding of social order, they are and will continue to be deeply intertwined with the social attitudes of the time (3).

In the Second World War there was concern regarding the acute heat problems faced by soldiers inside tanks engaged in desert warfare. In 1942 Mills noted that tanks in these conditions 'quickly become veritable ovens in which the occupants suffer terrible torment' (20). He suggested that 'lining the inside of the turret with aluminium foil should greatly lessen this heating-up of the interior' (20). At this point, the emphasis on heat had changed from the avoidance of extreme heat to potential ways to improve conditions despite the heat. Concern over the thermal conditions of British ships sailing in tropical waters led to the establishment, in 1942, of the Royal Naval Personnel Research Committee (21). This body focused its attention on more specific effects of heat exposure; measuring the physiological effects of different levels of humidity, air speed, and radiant heat on bodies that had been acclimatised in the laboratory to high temperatures.

Later research in Singapore confirmed these results and investigated the levels of heat stress on bodies that had been both 'naturally acclimatised' in a tropical climate and 'maximally acclimatised' in the laboratory (22). It was concluded that efficiency declines with increasing environmental stress and that the ultimate limits for tolerance of heat could be improved through repeated exposure to heat. Heed would need to be taken of the type of occupation engaged in and the length of time of engagement in order to safeguard naval personnel (22). As well as an understanding of the more specific elements of heat exposure, this research took into account individual variation and presented this as a reason why their results should be interpreted with caution (22). However, during most of the wartime research and for some time afterwards, most research was done on healthy young men from the UK or US (23), so little account could be taken of physiologically different responses relating to age, gender, or health status.

It is only very recently that military women's responses to thermal stress have been the subject of research. In 2005 a survey of women's occupational health in the military reported that an analysis of 10 years of data from an investigation of Marine Corps recruits in summer training in North Carolina had identified rates of exertional heat illness (EHI) amongst women soldiers (24). It was found that although the numbers of female recruits affected by EHI were comparable to male recruits (taking into consideration that 10% of trainees were women) there was a significantly lower rate of severe cases of EHI demanding hospitalisation among women trainees in comparison with their male counterparts (24). The results of US-based Defence Women's Health Research Program (DWHRP) studies on heat, cold, and altitude exposures suggest that there are fewer differences between male and female responses than had been predicted (24). The stated political motivation behind this study is to show that 'the DoD (US Department of Defence) is interested in providing the best possible health protection and performance enhancement for military women' (24). Whether or not this is the case, it is clear that there is an interest in establishing this as accepted truth.

Problems related to heat stress have continued to occur during combat in hot environments. An inquest into the heatstroke-related death of Territorial Army Private Jason Smith found that, at the time of his death, British soldiers in Iraq were collapsing daily from heat exhaustion (25). The Deputy assistant coroner for Oxfordshire stated that the Private's death had resulted from a serious failure to recognise the difficulty he was having in adjusting to the climate (26). Following this inquiry an undisclosed US military contractor employed thermal physiology scientists at the University of Portsmouth to test thermal vests designed to keep soldiers cool while in combat in Iraq (27). The difficulties in maintaining health amongst its soldiers despite high temperatures is a continuing concern for the military forces and the current military focus is on technological solutions to the health challenges presented by heat exposure. The continuing focus on the segregation of individual bodies from environmental challenges to health turns a blind eye to the underlying political and economic causes of the ill health and injury of all those involved in war. A brief look at these documents reminds us that atmospheric conditions, in general, and heat, more specifically, have been considered within the framework of political and economic motivations that lie behind strategic military concerns.

Heat and work

At the turn of the century the British emphasis on the effects of heat focused on the possibility of adaptation in order to avoid heat exhaustion (15). It was noted that in

tropical climes 'neither men nor horses can perform any work involving muscular exertion, once the sun is well above the horizon' and thus it was advisable to 'get through the business during the hours of darkness' (15). Work of a sedentary character could be better undergone, it was thought, if a small amount of exercise was taken in the early hours, although 'exercise at this time of day should never ... be carried to the extent of producing fatigue, or the quality of the work done after it will be sure to suffer' (15). It is clear that these snippets of advice are aimed at the more privileged classes of the British in India as customs such as 'the morning ride' and the 'plunge in the swimming bath' and a 'dog's snooze' after lunch are mentioned. The general advice, though, is to 'adopt an arrangement of the working hours which is the outcome of centuries of experience of life under a vertical sun' (15).

In the first half of the 20th century there was a general concern over the effects of heat on output in various industrial settings in the UK. The Industrial Health Research Board (IHRB) investigated the effects of heat in factories and collieries as well as potential ways to increase production by avoiding the adverse effects of high temperatures. In one IHRB report it was found that the output levels in tinplate manufacture varied with the atmospheric temperature, and the seasonal variability in output was higher in factories where there were no ventilation systems bringing in fresh air from outside (28). The IHRB reports were published with titles such as 'Two Contributions to the Experimental Study of the Menstrual Cycle. I. Its Influence on Mental and Muscular Efficiency. II. Its Relation to General Functional Ability' (29), 'A Study of Absenteeism in a Group of Ten Collieries' (4), and 'Sickness, Absence and Labour Wastage' (30). These titles give the impression that one of the main aims of investigations into atmospheric conditions in the workplace during these decades was to safeguard high work outputs rather than prioritising the health of the workers.

During the 1970s the motivational factor of avoiding industrial problems was still leading scientists to conduct research into heat tolerance and the best ways to reduce heat loads in factories and mines (23). A shift away from a focus on heat tolerance and towards the aim of diminishing heat exposure led to a concentration on engineering solutions (23). Solutions such as reflective shiny surfaces interposed between the worker and the heat source or the use of reflective clothing to reduce the absorption of radiant heat were promoted (23). The focus here is on isolation of the singular body, away from the heat source, and can be seen as an extension of the idea that human health is maintained in spite of, rather than in interaction with the environment.

In the same decade, a cultural anthropologist working for the US Army Research Institute of Environmental Medicine published a 'Special Technical Report' on heat stress and culture in North India (31). Planalp offers his interpretations of the hugely geographically and culturally varied 'villages of North India' with some reference to its 'vast and varied population' (31). However, he details many ways in which people are, themselves, able to avoid extremes of heat (31). These range from working to a flexible schedule in agricultural settings; completing semi-sedentary and portable work under the shade of trees; or adopting a 'summer schedule' in small businesses, large retail stores, and in courts, schools, and offices (31). Although funded by the military, the focus of this report was on the day-to-day lives of people living in the Plains of Northern India. The focus here, from the point of view of its military funding, was to understand the complex group of variables including age, activity, nutritional state, health, and cultural behaviour patterns that affect human adaptation and effective performance in extreme environmental heat (31).

It should be noted that literature focusing on heat-related occupational health is clearly highly gendered. There has historically been very little focus on the occupational health of women. This may be partly because much of women's home and family-based labour has been under-recorded and undervalued (32). In the information regarding women's occupational health that is available, it is often difficult to understand the distinctions between men's and women's occupational health profile because the data is presented as an aggregation of statistics relating to men and women (32). The lack of focus on women at work is reflected in academic analyses of heat-related occupational health.

Renewed interest in occupational health and the economic consequences of rising surface temperatures has developed in the shadow of climate change modelling. With increasing global surface temperatures as a result of anthropogenic GHG climate forcing, widespread changes in extreme temperatures have been observed (33, 34). In the last 50 years, hot days, hot nights, and heat waves have become more frequent (34). Humans are unable to tolerate wet-bulb temperatures above 35°C; this is a matter of particular concern in longer-term projections of global mean temperatures, in which increases of 10–12°C are not off the predictive scale for the next three centuries (35).

As part of increasing concern about these changes at government and institutional levels there has been more focus on how to deal with the direct health effects of heat exposure. In 2006 the British National Health Service published a short guide, which suggests how to avoid bodily overheating, heat exhaustion, and heatstroke (36). For non-medically trained people, this guide offers basic advice about what to do if a heat wave is forecast; this includes advice to plan the day's activities in a way that allows an avoidance of heat and ensures the ability to

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drink regularly. If symptoms develop, it is suggested that the person should be moved somewhere cool, sprinkled with cold water, and given water to drink (36). It is clear that heat exposure is increasingly being understood amongst health institutions as a risk.

Similarly the medical research into heat exposure and heatstroke has increased, with findings that indicate that heatstroke-related multi-organ dysfunction is the result of a complex interrelationship of physiological responses associated with hyperthermia, the direct cytotoxicity of heat, and the inflammatory and coagulation responses of the host (6). The effects of pharmacologic agents in accelerating cooling have been investigated and have been found not to be helpful in treatment (6). It is also increasingly recognised that social determinants and personal characteristics will affect the vulnerability of some people to heat exposure more than others. These scales of investigation will continue to be necessary to further aid in identifying groups at particular risk of heatstroke in order to provide better prophylactic care (37).

In more recent years, growing importance has been attributed to the effects of 'global heating' (7) on economic output at country level (9). However, it is argued that attention to the association between occupational heat stress and health status has still been lacking (38) as has a focus on the economic consequences of rising temperatures (9). Most modelling has focused on the effects of rising temperatures on the agricultural sector with its associated repercussions for the economy. However, Hsiang claims that in Caribbean basin countries, a short-term increase in surface temperature can also be linked to reductions in economic output across a range of non-agricultural industries that were not previously thought to be vulnerable to climate change (9). While this study may not provide conclusive evidence of the relative impacts of rising temperatures on the agricultural and non-agricultural industries of Caribbean basin countries, it contributes to the debate about the ways that economic output is already affected and will continue to be affected by rising temperatures. The mounting focus on economic output may also reflect growing efforts to guide policy decision-making bodies.

Kjellstrom et al. (39) argue that the rising temperatures associated with global climate change will particularly affect people in labouring occupations in low- and middle-income countries. This adds to the health inequities associated with climate change and must be addressed through long-term plans for adaptation in relation to the health threats of heat exposure (39). A study of a large national cohort of Thai workers found that heat stress was reported by nearly 20% of participants and was found to be strongly associated with overall ill health and psychological distress (38). More work is needed to quantify these relationships in different types of work scenarios, for example, in situations where work is 'self-paced' (39). Similarly, more research into appropriate preventive measures in specific occupational conditions and work scenarios will be increasingly necessary (39). This work must take into account the geographical variability that is expected in climate projections (34) and to do this the impacts of rising temperatures on working people can be assessed using local climate data (38, 39). It is clear that these more specific links between heat exposure, occupational health, overall health, and psychological distress need more attention. This approach is one that has the capacity to – and must – combine the intertwined issues related to health, economics, and power as well as long- and short-term environmental variability. In order to understand the present experiences of increasing temperatures, we must get inside all of those 'excessive connections and unruly categories' (3).

Conclusions

In this historical review of some of the Euro-American literature on heat exposure, heat stress and heatstroke, there are some structuring issues that recur throughout. The focus on heat exposure through the lens of military-related medical research illustrates the importance of systemic economic and political factors in directing medical advances. Similarly, the earlier racist and colonialist military discourses, as well as the male-centred approaches to occupational health, can be seen to highlight the importance of social determinants of medical aspirations and understandings. This, while not undermining current medical understandings of heat exposure, reminds us that there is no segregation between the technical, the medical and the social (3).

As the literature progresses, we can see changes in the scale of understandings of heat exposure and its health-related effects. In the late 19th century, heat stroke is understood through an analysis of symptoms, taking little note of personal characteristics affecting heat tolerance. Similarly, prevention of heat exposure moves from simple avoidance of heat to the development of complex engineering solutions. It is important to note here that the more recent 'scales' of analysis of heat-related injury are increasingly bifurcated. Thus, understandings of heat-related injuries are split between analyses of social determinants of heat-related health risks and increasingly complex clinical observations (6, 37). Perhaps an integration of these two sets of explanations of the causes of heat stress and heatstroke could further benefit future investigations.

Another of the structuring issues throughout this literature is the positioning of the human being in relation to the environment, based around a vision of singular bodies with stable boundaries between inside and outside. The understanding of this type of body has

increasingly been questioned as it has become clear that these separations exist because they have been made to (40). It could be argued that this vision of the body has been present in many military and work-based efforts to isolate the individual from heat exposure, rather than attempting to understand the wider systemic factors which present challenges to the maintenance of health. The relationship between the human body, politico-economic practices, cultural contexts, and environmental conditions is beginning to play more of a part in recent analyses of rising temperatures as an element of global climate change (41). The impacts of climate change are not uniformly distributed, and adaptive capacity is dependent on institutional and economic dynamics (42). Although many populations of the 'Global South' have historically demonstrated resilience to varying climates (43), it is clear that the burden of climate change is disproportionately affecting low-income countries (44, 45). Further research into appropriate measures with the capacity to mitigate the health effects of heat exposure amongst working people (39) must be done in order to contribute to efforts to reduce the growing inequities associated with climate change.

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