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REVIEW

Occupational Heat Stress and Kidney Health: From Farms to Factories

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Millions of workers around the world are exposed to high temperatures, intense physical activity, and lax labor practices that do not allow for sufficient rehydration breaks. The extent and consequences of heat exposure in different occupational settings, countries, and cultural contexts is not well studied. We conducted an in-depth review to examine the known effects of occupational heat stress on the kidney. We also examined methods of heat-stress assessment, strategies for prevention and mitigation, and the economic consequences of occupational heat stress. Our descriptive review summarizes emerging evidence that extreme occupational heat stress combined with chronic dehydration may contribute to the development of CKD and ultimately kidney failure. Rising global temperatures, coupled with decreasing access to clean drinking water, may exacerbate the effects of heat exposure in both outdoor and indoor workers who are exposed to chronic heat stress and recurrent dehydration. These changes create an urgent need for health researchers and industry to identify work practices that contribute to heat-stress nephropathy, and to test targeted, robust prevention and mitigation strategies. Preventing occupational heat stress presents a great challenge for a concerted multidisciplinary effort from employers, health authorities, engineers, researchers, and governments.

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Until recently, chronic kidney disease (CKD) was thought to be primarily a consequence of other chronic conditions such as diabetes mellitus and hypertension. Acute kidney injury (AKI), and especially recurrent episodes of AKI, have now also been shown to be associated with CKD.[1] In the past few years, environmental and occupational factors have also been associated with CKD, especially in so-called CKD hotspots, which are defined as countries, regions, or ethnicities with a higher than average incidence of CKD.[2] CKD of unknown etiology (CKDu) has become a newly categorized condition, a diagnosis of exclusion, made when a patient fulfills the Kidney Disease Improving Global Outcomes (KDIGO) CKD criteria without evidence of a recognized cause such as diabetes, hypertension, genetic disease, or glomerulonephritis.[3] The incidence of CKDu is higher in most CKD hotspots, such as Sri Lanka, India (state of Andhra Pradesh), Pakistan, and Egypt, and coastal zones of Nicaragua, El Salvador, and Costa Rica. The causal relationship of environmental and occupational factors and CKDu has not been clearly delineated. However, study of CKDu has been recognized by the International Society of Nephrology (ISN) as a global research priority.[4]

Approximately 40% of the world's population lives in a climate zone where the normal daytime temperatures exceed 30°C most of the year. In these regions, many workers have physically demanding jobs, are paid by output, lack employment alternatives and health insurance, and live in substandard housing, all of which can independently increase the risk for heat-related morbidity and mortality.[5,6] As the frequency of hot days and heat waves is expected to increase globally over the coming decades,[7] the risk of heat-related illnesses and injuries is also expected to rise.[8–10]

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The threat of excessive occupational heat exposure and its consequences, although also present in developed countries and in formal working sectors, is particularly high in tropical, low-to-middle-income countries where large informal sectors of workers exist, often operating in hot, densely populated environments with high physical workloads and scant safety regulations.[8,11] The lack of representation of these workers in the social security systems, as well as not being able to count on organized public health systems in these countries, make community-based prevalence studies highly necessary to address this topic.

Occupational heat exposure may affect both outdoor and indoor workers who perform activities in hot environments, such as near furnaces, ovens, and boilers.[12] There is limited research on the effects of chronic indoor occupational heat stress on the kidney health and function. As such, we conducted an in-depth descriptive review of the known effects of indoor occupational heat stress on kidney function. We also examined methods of heat-stress assessment, strategies for prevention and mitigation, and the economic consequences of occupational heat stress.

Heat Stress

Heat stress is considered to be the sum of the heat generated in the body (metabolic heat), plus the heat gained from the environment (environmental heat), minus the heat lost from the body to the environment.[13] Environmental and metabolic heat stress result in physiological responses (heat strain) to promote the transfer of heat from the body back to the environment to maintain core body temperature.[14] The body's heat balance is determined by 6 fundamental factors: 4 climatic (air temperature, radiant temperature, humidity, and air movement) and 2 nonclimatic (clothing and the metabolic heat produced during physical activities).[8] Heat dissipation occurs through dry heat loss (radiation and convection) and evaporative heat loss (sweating) (Figure 1).[15] Heat stress results in heat-related occupational illnesses, injuries, and reduced productivity, when sweat evaporation is insufficient, and other physiological changes cannot prevent the core body temperature from rising.[13] If temperature rises beyond 39°C, heat stroke may occur, with eventual failure of the central nervous thermoregulatory system.[16,17]

Heat stress often occurs in conjunction with dehydration, and manifests as a range of heat-related symptoms such as fatigue, headache, muscle cramps, weakness, dizziness, nausea, vomiting, tachycardia, hyperventilation, ataxia, hypotension, syncope, and transient alteration in mental status.[18] The occurrence of heat-related illnesses in an individual or among a group of workers in a hot environment represents "sentinel health events," which indicate that heat control measures, medical screening, or environmental monitoring measures may be inadequate.[19] Individual tolerance to heat stress is variable, and is affected by acclimation, pre-existing disease, clothing, age, gender, level of physical activity, and body size.[20,21]

Heat Stress Assessment

International agencies responsible for preventing the health risk of occupational heat stress have formulated heat stress standards and guidelines that specify upper

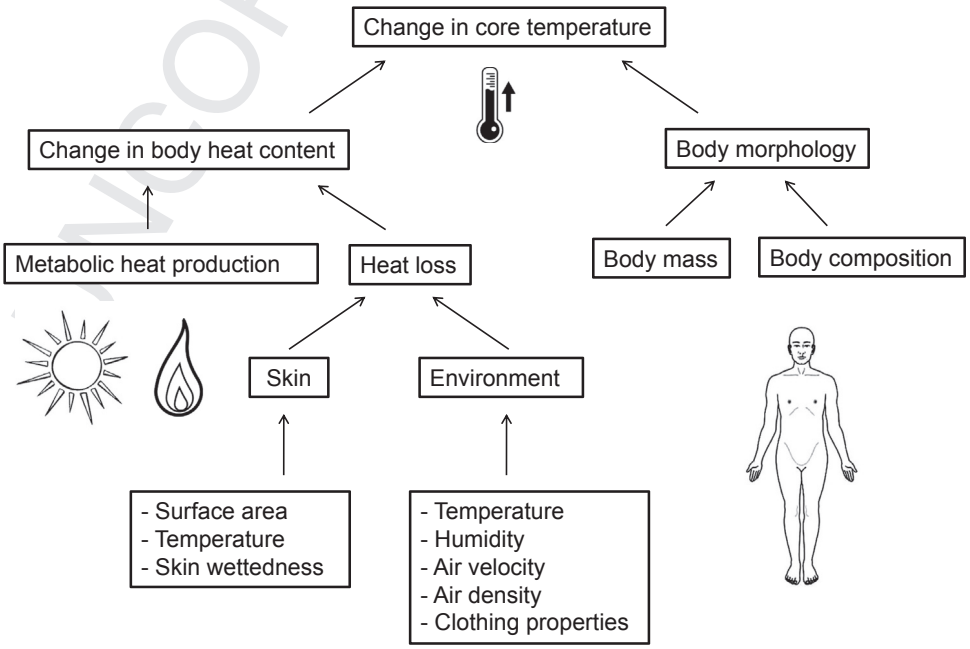

Figure 1. Biophysical factors affecting the change in core temperature during exercise and environmental heat exposure.[20]