

Heat, UV Radiation, and Other Related Atmospheric Stressors: Exposure Pathways, Health Effects, and Adaptation Needs

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Heat and ultraviolet (UV) radiation are among the most consequential environmental stressors intensified by anthropogenic climate change. Exposure to both types affects human health, yet they differ fundamentally in their temporal dynamics, physiological pathways, and systemic consequences [1,2]. Heat acts as an acute, whole-body stressor, whereas UV radiation primarily affects the skin, eyes, and immune system through cumulative photobiological mechanisms [3]. Importantly, heat and UV radiation do not necessarily occur simultaneously, as their atmospheric drivers differ [4,5]. High UV levels may occur during cool, clear-sky days, while heatwaves can coincide with haze or cloud cover that reduces UV intensity. In addition, peaks of heat and UV and other related atmospheric stressors may occur in combination and start or take place at different times of the year.

Both stressors interact with additional environmental hazards, such as ozone, particulate matter, pollen, drought, and thunderstorms, creating complex multi-hazard exposure environments [6,7]. Understanding these interactions is essential for designing effective public-health and climate adaptation strategies and/or measures [8]. This summary synthesizes current scientific evidence and highlights the most relevant short- and long-term considerations in the combined context of heat and UV exposure.

The significance of heat and UV radiation in a changing climate is substantial. Rising global temperatures increase the frequency, duration, and intensity of heatwaves, which are among the deadliest natural hazards worldwide [9,10]. UV radiation levels remain high, particularly under clear-sky conditions, in the springtime, and at higher altitudes [5]. Urban environments amplify heat exposure through the urban heat island effect, reduced ventilation, and limited shading, factors extensively documented in urban bioclimatology. Concurrently, climate-driven changes in cloud cover and stratospheric ozone influence UV exposure patterns [5,11].

Demographic trends, such as population aging and the increasing prevalence of chronic diseases, further heighten vulnerability. Behavioural patterns, including outdoor recreation, occupational exposure, and mobility, shape both heat and UV exposure. Socioeconomic disparities also influence risk, as access to cooling, shade, and protective resources is unevenly distributed [12].

High exposure to heat and UV radiation leads to distinct negative health impacts. Heat affects multiple physiological systems: Thermoregulatory strain leads to dehydration, excessive sweating, and, in severe cases, anhidrosis. Cardiovascular stress manifests as tachycardia, hypotension, and arrhythmia. Neurological dysfunction includes dizziness, confusion, and seizures. Renal impacts range from acute kidney injury to chronic

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kidney disease of non-traditional origin [13]. Respiratory burden increases through exacerbation of COPD and asthma. Mental-health effects include irritability, aggression, sleep disturbances, and increased psychiatric admissions [14]. Severe outcomes include heat exhaustion and heat stroke, the latter being a medical emergency with high mortality.

UV radiation primarily affects exposed tissues. Acute effects include sunburn (erythema), photokeratitis, and photoconjunctivitis [8]. Chronic exposure leads to skin cancers, including melanoma, basal cell carcinoma, and squamous cell carcinoma; photoaging; and cataract formation [3,15,16]. UV radiation also modulates immune responses, contributing to local immunosuppression [17]. Recent studies highlight additional systemic effects, including interactions with vitamin D metabolism and inflammatory pathways [18].

Despite these risks, heat and UV radiation also have positive effects. Moderate warmth can promote outdoor physical activity, improve mood, and reduce cold-related mortality [9]. UV exposure enables vitamin D synthesis [19] and is used therapeutically in dermatology [20]. These benefits are strongly dose-dependent and must be balanced against environmental risks.

Heat and UV exposure differ markedly in their symptom profiles. Heat exposure produces systemic symptoms with a rapid onset (such as dehydration, cardiovascular collapse, and neurological impairment), whereas UV exposure causes localized symptoms with delayed onset, such as erythema, blistering, and ocular irritation. Chronic UV exposure contributes to skin cancer and cataract formation, while chronic heat exposure contributes to renal and cardiovascular strain.

Heat and UV radiation do not necessarily coincide. UV exposure depends on solar elevation, cloud cover, aerosols, ozone concentration, and altitude [4,5], whereas heat depends on air temperature, humidity, wind, and radiation fluxes (solar and terrestrial). As previously mentioned, this decoupling means that combined exposure assessments must treat heat and UV separately. Recent research emphasizes the need for multi-hazard frameworks that integrate thermal stress, UV exposure, and air-quality parameters [12].

In terms of comparative public-health relevance, heat currently poses the more acute and life-threatening risk, while UV radiation contributes to a larger long-term disease burden. Heatwaves cause immediate spikes in mortality and hospitalization, whereas UV radiation contributes to highly prevalent but mostly non-fatal chronic conditions. Climate change is increasing heat-related mortality faster than UV-related mortality [21]. Furthermore, from an urban risk perspective, extreme events with high impacts but long return periods are as urgent as lower-impact exposures that occur with near-sequential periodicity in cities, as both place sustained and cumulative pressure on public health systems, infrastructure, and daily life.

Heatwaves increase emergency-department visits, ambulance dispatches, hospital admissions, and mortality [9]. UV exposure increases already-high dermatology case-loads, increasing skin cancer incidence, ophthalmology demand, and long-term treatment costs [3,16]. Heat stresses acute care; UV stresses chronic care.

Interactions with pollen, ozone, air pollution, and weather extremes further complicate exposure. High temperatures and UV intensity accelerate photochemical ozone formation, increasing cardiopulmonary risk [6]. Heat enhances pollen production and season length, while UV modifies pollen allergenicity [7]. Air pollutants amplify oxidative stress and respiratory morbidity [22]. Thunderstorms can fragment pollen, causing “thunderstorm asthma” [20]. Drought increases dust and particulate matter. Heatwaves often coincide with stagnant air masses that trap pollutants.

Adaptation strategies and associated measures must therefore be multi-layered. Heat adaptation includes heat-health action plans, early-warning systems, urban greening, shading, reflective materials, ventilation corridors, occupational heat protection, and

cooling centres [23–27]. UV protection includes shade structures, sun-protective clothing, sunscreen, UV-index communication and warnings, regulation of artificial UV sources, and skin cancer screening programs. Fragmented single-hazard approaches are no longer sufficient. Integrated strategies combine heat, UV, ozone, and pollen forecasts and apply climate-sensitive urban planning and design principals [8,11,28].

Heat and UV radiation represent distinct but interrelated climate-health hazards. Their combined effects with air pollution, pollen, and extreme weather create complex exposure environments that challenge public-health systems. Integrated adaptation strategies, combining acute response capacity with long-term prevention, are essential for building resilience.

Heat and UV radiation are major environmental determinants of human health and well-being. Rising temperatures, more frequent heatwaves, and changing UV exposure patterns under climate change increase the risk of morbidity, mortality, and reduced labour capacity. At the same time, moderate warmth and controlled UV exposure can provide physiological and psychological benefits. Understanding both the risks and potential benefits is essential for developing effective public-health and adaptation strategies, which are crucial for the development of heat-health action plans or, in general, climate actions plans—and not only for urban areas. Crucially, the negative aspects of heat and UV exposure must be translated into actionable opportunities within the public realm, guiding climate-sensitive urban design, planning, and management interventions that actively support human life, health, and daily activity.

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