Review Article

Heat waves and Public Health: Understanding the Rising Threat of Extreme Heat Events in Gulf region

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Abstract

Heat waves are an escalating public health threat in the Gulf region, driven by climate change and rapid urbanization. This review examines the rising frequency, intensity, and duration of extreme heat events in Gulf Cooperation Council (GCC) countries, highlighting their severe health impacts, particularly on vulnerable populations such as migrant laborers, the elderly, children, and individuals with chronic illnesses. The region has experienced significant warming, with temperatures rising approximately 0.5-0.6°C per decade, exacerbating urban heat island (UHI) effects and creating microclimates that amplify heat stress. Projections under high-emission scenarios suggest temperature increases of 4.1-5.8°C by the late 21st century, potentially rendering parts of the region uninhabitable. Extreme heat directly impacts health, causing heat exhaustion, heatstroke, and exacerbating cardiovascular, respiratory, and renal diseases. Epidemiological data from GCC especially Kuwait and Saudi Arabia reveal spikes in hospitalizations and mortality during heat waves, with migrant workers facing disproportionate risks due to occupational exposure. The UHI effect, compounded by dense infrastructure and limited green spaces, further intensifies health risks. Despite adaptation measures like midday work bans and urban cooling initiatives, policy gaps persist in health surveillance, labor protections, and urban planning. This review underscores the urgent need for comprehensive heat-health action plans, stricter enforcement of labor regulations, and sustainable urban design to mitigate heat impacts. Future research should focus on high-resolution exposure assessments, interdisciplinary climate-health modeling, and targeted interventions for at-risk groups. Addressing these challenges is critical to safeguarding public health as the Gulf region faces unprecedented warming, ensuring resilience against the growing threat of extreme heat events.

Keywords: Climate Change; Heat waves; Global warming; Public health; Gulf region

1. Introduction

Heat wave is a major and fast-growing threat to public health due to climate change and massive urbanization in the world. The extreme heat events for several days cause the drastic health effects to all but especially to vulnerable population of world (Marcotullio et al., 2022; Xu et al., 2025). Understanding the complexities of this hazard is critical for developing effective mitigation and adaptation strategies at the individual, community, and policy levels. Extreme heat has the potential to exacerbate pre-existing health disorders and create new ones (Woodland et al., 2023). The body's ability to regulate its internal temperature can be overridden, resulting in heat-related disorders such as heat stroke, heat exhaustion, heat cramps, and heat rash. The cardiovascular, neurological, pulmonary, and renal systems are especially vulnerable to harm, and mental health may be substantially impacted (Bell et al., 2024).

Extreme heat events have been linked to higher death and morbidity rates, notably among the elderly, children, outdoor laborers, and those with pre-existing diseases (Al Khatib et al., 2025; Lindsay et al., 2023). The few most famous examples of recent years heat waves worldwide are the European heat wave 2003 which caused 30,000 to 75000 excessive death in Europe alone, the Russian heat wave 2010 caused the 55000 death in Russia (Wedler et al., 2023). Similarly, Greece heat wave 2007 and Pakistan heat wave 2015 caused thousands of deaths (Ebi et al., 2021). The other devastating impacts of heat wave events include the destruction of infrastructure, high demand of electricity, power outrage ecosystem problems, impaired agriculture and increased consumption of water in domestic and household purposes (Haque, 2024; Khan et al., 2024). The current review article comprehensively evaluate the public health effects caused by extreme heat waves and continuous threat of increasing the number of extreme heat events in Gulf region in past decade.

The Gulf region, which includes Saudi Arabia, the United Arab Emirates, Kuwait, Bahrain, Qatar, and Oman, is experiencing an unprecedented surge in high temperature occurrences, known as heat waves (Hereher, 2020). The extreme heat wave events are becoming more common and extreme as the effects of global climate change accelerate, posing a significant and ever-increasing hazard to public health across the region (Mittal, 2025). Heat waves in the Gulf region are more than just environmental issues; they are also severe public health problems that require urgent attention (Hamed et al., 2024; Zittis et al., 2022). The **Figure 1** shows the topographical map of countries including in Arabian Gulf region.

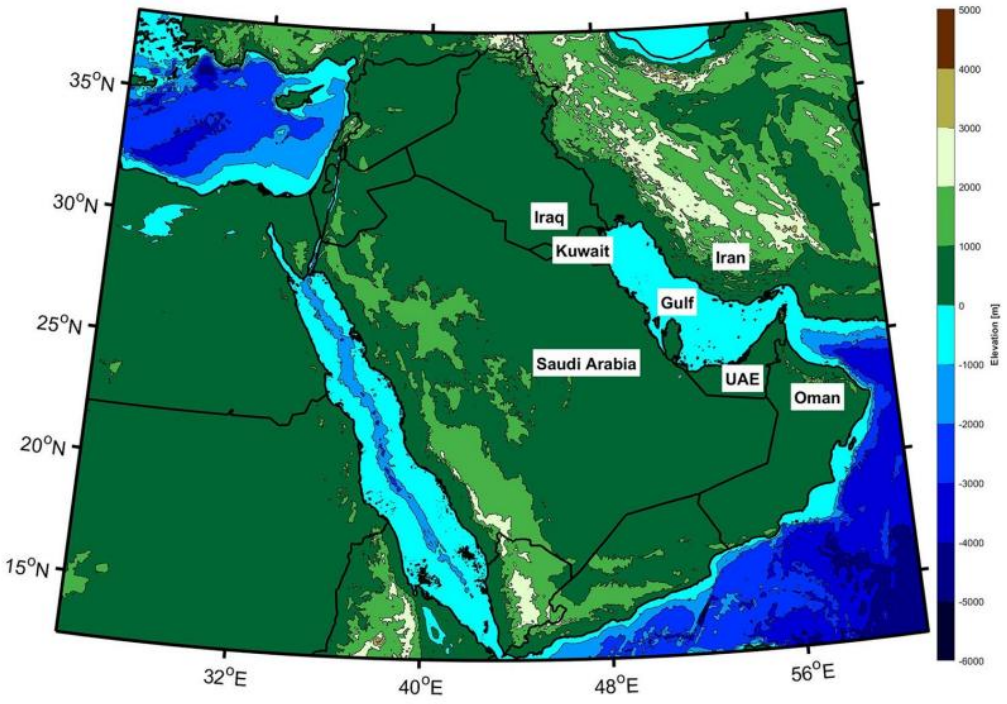

Figure 1. The topographical map of Gulf region countries (Source: (Al Senafi et al., 2024)).

The Gulf region has historically and traditionally had a hot desert climate, but in the last decade or two, there has been a significant rise in heat wave occurrences and duration, which is a result of human climate change, exacerbated by local impacts such as fast urbanization and urban heat island (UHI) (Zittis et al., 2022). The conversion of natural landscapes to concrete and asphalt in

emerging cities traps heat, creating microclimates with temperatures that exceed natural desert extremes (Alhusaiki, 2024; Baliello, 2020). This UHI effect exacerbates the dangers of climate change by increasing the vulnerability of urban populations to heat-related illnesses and mortality (Heaviside, 2020). According to scientific forecasts, if carbon emissions continue at their current rate, significant areas of the Gulf region may become uninhabitable by the middle of the century due to unbearable heat stress (Zumbraegel, 2022). There is an urgent need to address this crisis as it poses extreme threat to masses of population (Brimicombe et al., 2024; Khan et al., 2024).

The implications of rising temperatures in the Gulf for public health are massive and complex. Heat waves are linked to a variety of negative health consequences, including heat exhaustion, heat stroke, dehydration, and worsening of chronic conditions such as cardiovascular and respiratory diseases. During extreme heat events, at-risk populations such as the elderly, children, pregnant women, outdoor laborers, and persons with pre-existing illnesses have an elevated risk of morbidity and mortality (Eldos et al., 2025). In Kuwait, studies have found a considerable increase in cardiovascular disease (CVD) hospitalizations during periods of intense heat, with relative risks increasing rapidly at temperatures above 40°C and even some times above 50 °C. According to forecasts, the pressure of heat-related cardiovascular admissions in Kuwait may only increase by 4.44% in extreme and moderate climate change scenarios by 2100 (Ahmadalipour et al., 2019; Alwadi et al., 2024). Similar patterns have been observed elsewhere in the region, with heat waves increasing all cause and death from cardiovascular disease throughout Iran and the larger Middle East and North Africa region.

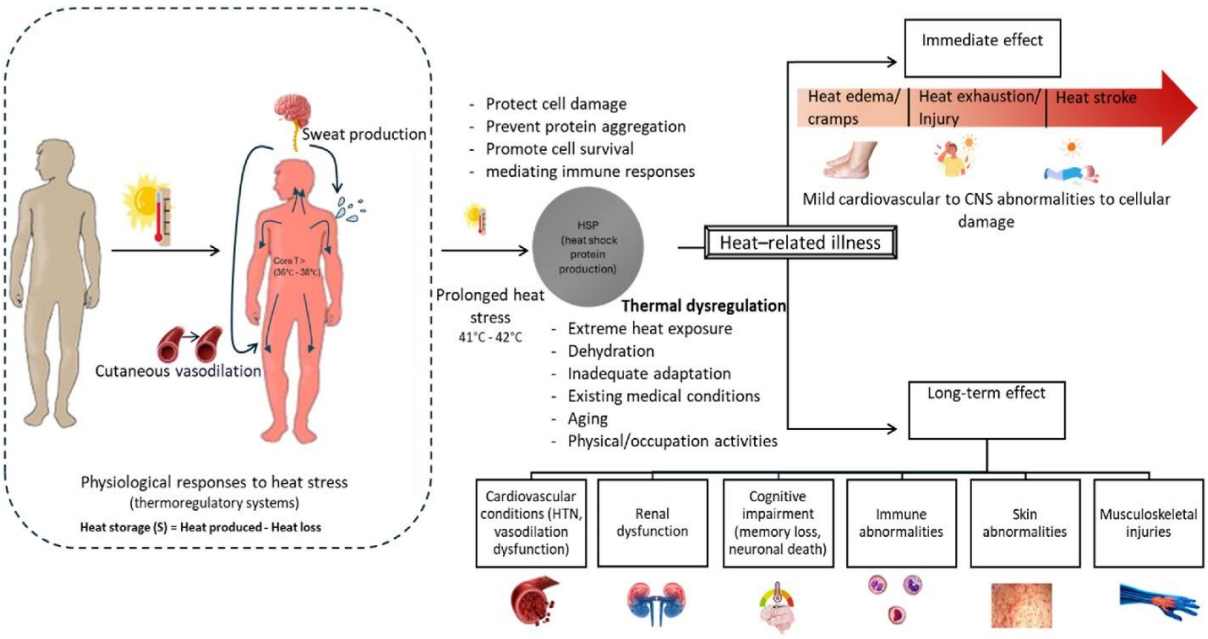

Figure 2. Physiological Responses and diseases caused by Heat wave (Source: (Eldos et al., 2025).

The extreme heat is devastating the lives of migrant labors working in the Gulf region. They belong to Asia and Africa. Their nature of work often involve occupational settings and often inadequate protections (Wodon et al., 2014). This migratory labor working in different sectors like agriculture, manufacturing, construction and other physically demanding sectors faces high risks of exposure to these extreme heat events and serious health issues like heat stroke, dehydration and chronic kidney diseases. The Government in Gulf region especially in Qatar adapting measures to tackle the issue by posing ban on middy day work and temperature based working limitations. The countries in Gulf region must adopt some holistic policy measures in order to protect their work force by reducing daily working hours, improving their living conditions, providing them with mandatory rest breaks, working only in shaded areas, and access availability of drinking water in working areas. These measures are essential for the protection of vulnerable population (Eldos et al., 2025; Masood et al., 2024).

In addition to the direct health effects, extreme heat exacerbates other environmental and social health issues (**Figure *2***). Heat also stimulates the development of ozone and other ground-level air pollutants, worsens respiratory illnesses, and raises respiratory morbidity and mortality rates. Heat waves put additional burden on healthcare systems, as do spikes in emergency visits and hospital admissions, which overload the Gulf region's healthcare infrastructure (Edmonds et al., 2023). As a result, the country's economic progress is hindered by inadequate health and infrastructure. Increasing heat waves in the Gulf demonstrate how serious the global climate situation is, and it can only be addressed with measures suited to each location. Science-based evidence emphasizes the relevance of urban planning, disaster preparedness, workplace health and safety, and climate change policy. Greater use of renewable energy, updating green infrastructure, and creating sustainable cities can all help to reduce the impact of UHIs as well as an area's total temperature. The GCC Counties must develop public health mechanisms to handle crises involving the health effects of heat (Brimicombe et al., 2024; Hess et al., 2023).

This comprehensive review article aims to provide the thorough understanding of the impact of heat wave on public health in Gulf region countries. It particularly focus on focus on the history of heat wave events in Gulf region, epidemiological patterns, health effects on vulnerable population, socioeconomic issues due to extreme heat events. The study discusses policy and practical approaches to mitigate the effects of heat wave events. This study help us understand the complex interplay of climate change, urbanization, and public health in the Gulf region, educating researchers, policymakers, and human health practitioners about the pressing problems and opportunities for safeguarding health during extreme health events worldwide especially in gulf region.

2. Climate Trends and Heat wave Characteristics in the Gulf Region

Over recent decades the Gulf region has warmed markedly. Satellite and station data show average near-surface air temperatures rising roughly 0.5-0.6 °C per decade across the Gulf Cooperation Council (GCC) land areas (Raymond et al., 2024). For example, Hereher (2022) reports an overall *net* land warming of ≈0.6 °C/decade (2000–2020) for the GCC, with peak warming up to ~2 °C/decade in Kuwait (Hereher, 2022). Concurrently, the frequency of extreme heat events has surged: Saudi Arabia gained ~21 more "warm nights" per year in 2019 than in 1979. Similarly, independent analyses of station networks find multi-decade Arabian-peninsula warming of roughly 0.55–0.63 °C/decade in recent decades. These trends exceed the global mean rate and reflect the region's pronounced climate sensitivity (Al Senafi et al., 2024; Alghamdi, 2018).

Heat extremes are already exceptional. Observationally, mid-summer day temperatures routinely exceed 45-50 °C in inland Gulf locales, while coastal thermal conditions combine high heat with extreme humidity. Coastal areas regularly experience dew points above 30 °C; recent studies document nighttime humid-heat maxima along the Arabian Gulf coast driven by warm, moisture-laden sea breezes. These wet-bulb peaks often occur at night rather than daytime, underscoring the importance of humidity in the Gulf's heat stress. In sum, both mean and extreme heat have intensified across the GCC in recent decades, as dry-land temperatures and coastal wet-bulb values have risen faster than global averages (Hereher, 2020; Masson-Delmotte et al., 2021; Raymond et al., 2024).

2.2. Projected Climate Change Scenarios

Model projections indicate even larger Gulf warming under twenty-first-century greenhouse-gas scenarios (Al Senafi et al., 2024). Multimodel analyses (CMIP6) show that under a high-emission

trajectory (approximately RCP8.5/SSP5-8.5), annual-mean temperatures over the Arabian Peninsula rise by several degrees. For example, Almazroui et al. (2020) project that compared to 1981–2010 climatology, Gulf temperatures will increase by roughly 1.8-2.7 °C by mid-century (2030-2059) and 4.1-5.8 °C by late century (2070-2099) under SSP5-8.5. Even under a moderate scenario (SSP2-4.5, akin to RCP4.5), mean temperatures climb by ~1.4-2.1 °C (midcentury) and ~2.3-3.4 °C (end-century). In all scenarios, summer heat and maximum temperatures warm more than winters, and the northern Gulf (e.g. Kuwait, northern Saudi) tends to warm fastest (Almazroui et al., 2020).

i. **SSP1-2.6 (low emissions):** ~+1.2-1.9 °C by 2030–2059; +1.2-2.1 °C by 2070–2099.
ii. **SSP2-4.5 (medium emissions):** ~+1.4-2.1 °C by 2030–2059; +2.3-3.4 °C by 2070–2099.
iii. **SSP5-8.5 (high emissions):** ~+1.8-2.7 °C by 2030–2059; +4.1-5.8 °C by 2070–2099.

Downscaled regional models reinforce these results. High-resolution CMIP6 datasets (NEX-GDDP) show that by century's end (relative to 1995–2014), Arabian summer daytime maxima could be up to +6 °C under SSP5-8.5. Crucially, heat-wave events become more frequent, longer, and more intense (Vinodhkumar et al., 2024). A CORDEX regional projection study finds that by 2100 about *50–80%* of warm-season days in most Gulf cities will meet heat-wave criteria, versus only ~15–20% today. In practical terms, under RCP4.5 roughly half of summer days become heat-wave days, while under RCP8.5 about half of cities see >70% of summer days as heat waves. Both the mean and maximum intensity of heat waves also climb markedly. The GCC projections indicate dramatic future heat amplification: even moderate emission reductions yield 2-3 °C warming (with far more hot days), whereas business-as-usual yields 5-6 °C warming and a near-ubiquitous heat-wave season by the late century (Varela et al., 2020).

2.3. Urban Heat Island Effect

Rapid urbanization in Gulf cities has intensified local heat (El Kenawy et al., 2024). Vast expanses of concrete, asphalt, and dark building materials absorb and re-emit solar energy, while scarce vegetation and widespread air-conditioning waste heat, amplifying urban temperatures above rural surroundings (Abulibdeh, 2021; Barak, 2024). Satellite land-surface temperature analyses find substantial urban-rural contrasts. For example, Abulibdeh (2021) reports that across eight major GCC cities (Doha, Dubai, Riyadh, etc.), mean land-surface temperature differences of 1–5 °C between built-up and vegetated areas are typical (bare vs. green areas differ by up to 6–7 °C). Similarly, city-specific modeling in Doha finds nighttime UHI intensities up to 6.5 °C (urban air 6.5 °C hotter than surrounding rural air). Even more striking, coastal cities can develop a "cool island" effect during daytime: strong sea breezes can cool urban cores so much that daytime downtown temperatures are several degrees lower than the suburbs. In contrast**,** inland Riyadh (lacking sea breezes) tends to experience persistent nighttime UHI with minimal daytime relief (Abulibdeh, 2021).

Al Hurini et al. (2024) investigate the complex interplay between rising temperatures and health outcomes among adults in the United Arab Emirates (UAE), a region acutely vulnerable to climate change. The study expands the discourse beyond conventional focus on physical health by integrating mental and social health dimensions, which remain underexplored in arid climates. Utilizing a cross-sectional design, the authors surveyed 397 UAE residents via a structured questionnaire to assess heat exposure duration, physical symptoms, and self-reported mental and social health outcomes. Mental health was evaluated using the validated Depression, Anxiety, and Stress Scale (DASS-21). Statistical analyses (chi-square tests, SPSS v28) revealed significant associations between prolonged heat exposure (≥2 hours/day for 83.4% of participants) and adverse health outcomes. Physically, heat exhaustion predominated (86.4%), alongside heatstroke

(43.1%) and heat syncope (41.1%). Mental health burdens were pronounced, with 45.1% reporting anxiety, 35.5% depression, and 11.6% stress. Socially, 19.9-25.2% of participants described isolation, diminished social connectedness, and reduced relationship quality, underscoring heat's role in eroding communal ties. The study's strength lies in its holistic approach, bridging environmental epidemiology with psychosocial health. By framing heat as a multisystem stressor, the authors challenge policymakers to adopt integrated interventions. Recommendations include bolstering mental health infrastructure, fostering community resilience programs, and enhancing public health messaging to address heat's cascading effects. This research underscores the urgency of redefining heat mitigation strategies in climate-vulnerable regions. It advocates for interdisciplinary collaboration to safeguard not only physiological well-being but also psychological and social integrity in an era of escalating temperatures (Al Hurini, 2024).

Dense clusters of high-rise glass and concrete trap heat and impede airflow, while air-conditioning exhaust and vehicle emissions add anthropogenic heat. Studies point out that proximity of artificial structures, low albedo surfaces, and excess waste heat from buildings strongly intensify urban warming (Abdulmajeed, 2023; Rajeswari et al., 2024). Urban design in Gulf metropolises, especially extensive dark road networks and reflective skyscrapers thus reinforces the UHI (Abbas, 2024). In effect, urbanized districts routinely see surface or air temperatures several degrees above the regional mean: satellites and models show urban-to-rural LST differences on the order of 1-6 °C in Gulf cities. This exacerbates heat exposure for city residents: for instance, the modeled nighttime UHI in Doha can raise apparent heat indices in dense districts well above open desert levels (Abulibdeh, 2021).

Rapid urban growth has made Gulf urban areas much hotter than rural surroundings. Studies of Doha, Dubai, Riyadh, etc., document 2-7 °C higher daytime land-surface temperatures in urban zones relative to green areas. Building materials, energy use, and scarce vegetation drive this effect. Particularly at night, Gulf cities can remain several degrees hotter than the countryside (e.g. +6.5 °C in Doha). Thus, the UHI intensifies heat stress locally, compounding the broader warming and increasing health risks in GCC cities (Abulibdeh, 2021; Al-Ruzouq et al., 2022; El Mir, 2025; Rajeswari et al., 2024).

3. Public Health Impacts of Heat Waves

3.1. Physiological Mechanisms and Health Outcomes

Exposure to extreme heat challenges the body's thermoregulation. Normally, excess heat is dissipated by increasing skin blood flow and sweating. However, high humidity greatly impairs sweat evaporation, so hot, humid air traps heat and elevates core temperature. As temperature rises, heart rate and cardiac output climb to pump blood to the skin, markedly increasing cardiac workload (Eldos et al., 2025; Meade et al., 2025; Millyard et al., 2020). At the mild end of the spectrum, this leads to heat exhaustion (fatigue, dizziness, headache, muscle cramps) and heat syncope (**Figure 2**). In the Gulf climate, even moderate exertion under a hot sun or indoor airless conditions can precipitate dehydration and electrolyte losses (Brimicombe et al., 2024; Hess et al., 2023; Issa & Alrusayni, 2024).

When heat stress is extreme or prolonged, heatstroke can occur. By definition, (Baindara et al., 2025; Rastogi et al., 2025). At this point, thermoregulation has failed: proteins and enzymes begin to denature, and blood vessels leak. Heat stroke triggers a systemic inflammatory response and coagulation cascade. For example, studies of heatstroke patients show widespread endothelial

injury, disseminated intravascular coagulation, and immune cell activation leading to multi-organ failure (Chen et al.; Tsuchida & TSUCHIDA, 2025). Gut barriers can become permeable, allowing endotoxins into circulation and causing neuro-inflammation. In short, heatstroke can cause respiratory failure, liver and kidney shutdown, and severe CNS impairment (confusion, seizures, and coma). Mortality rates are high: untreated heatstroke is often fatal, and even with intensive care survival is uncertain (Patel et al., 2023; Zhang et al., 2024).

Even sub-lethal heat stress worsens chronic disease. Dehydration and vasodilation increase blood viscosity and cardiac strain, precipitating heart attacks or strokes in vulnerable patients. Recent human data confirm that acute heating raises heart rate, cardiac output and rate-pressure product (an index of cardiac workload), changes that can trigger myocardial ischemia or heart failure in patients with underlying coronary disease. The kidneys are also strained: they normally help conserve fluid and regulate electrolytes during heat, but prolonged dehydration and reduced blood pressure can cause acute kidney injury (AKI). Indeed, one review found that electrolyte disturbances and AKI are among the leading causes of heat-related hospitalization in the elderly. Over time, repeated heat stress and AKI episodes may contribute to chronic kidney disease (Chapman, Johnson, et al., 2021; Meade et al., 2025). Beyond physical illness, extreme heat affects mental well-being. Physiologically, heat exposure activates the stress hormone axis, raising cortisol and catecholamines, which can heighten irritability and anxiety (Rony & Alamgir, 2023). In fact, a recent systematic review of heat and mental health identified evidence that heat waves increase psychological stress and impair sleep. Participants in focus groups reported that high heat causes fatigue, social isolation (to avoid the outdoors), and anxiety about health risks (Baecker et al., 2025).

3.2. Epidemiological Evidence from the Gulf

Recent studies in the Gulf region have begun to quantify the human toll of heat waves (Al Khatib et al., 2025; Christidis et al., 2023; Hereher, 2022; Raymond et al., 2024; Varela et al., 2020). Model-based analyses for the broader Middle East note that current heat-related death rates are already elevated: one Lancet study estimated an average of ~2.1 heat-attributable deaths per 100,000 people per year across MENA countries under present conditions (Hajat et al., 2023). In the Gulf States, observational data confirm spikes in morbidity and mortality during heat extremes (Eldos et al., 2025; Zittis et al., 2022). For example, a large Kuwaiti analysis (2010-2019) linked heat to thousands of excess hospital admissions for cardiovascular disease. During that decade Kuwait recorded 263,182 CVD hospitalizations, of which an estimated 20,569 (≈7.8%) were attributable to extreme heat days. Relative risk of CVD admission climbed markedly on very hot days (e.g. RR≈1.33 at 43 °C vs the optimal temperature). These admissions included heart attacks and strokes that surged with temperature, indicating that heat waves are a major driver of cardiovascular hospital use in Kuwait (Alwadi et al., 2024).

In Saudi Arabia's Makkah region, researchers compared heat effects on local residents versus Hajj pilgrims. Over nine Hajj seasons (2006–2014), pilgrims (a largely elderly, international cohort) experienced very high heat mortality: elevated temperatures during pilgrimage were associated with 70.8% of deaths attributable to heat (95% CI 62.8–76.0%) (Yezli et al., 2023). By contrast, Mecca residents (who are acclimated and younger on average) showed no significant heat-related mortality. This striking finding underlines how acute heat waves, even of short duration, can trigger mass casualties in unadapted populations (Yezli et al., 2024). More generally, health systems report surges in emergency visits and hospitalizations during heat spells. Though Gulf-specific time-series are limited, international evidence is suggestive: for example, European studies find that during heat waves hospital admissions rise significantly for thromboembolic

events, renal disorders, respiratory illness and heatstroke. By analogy, Gulf hospitals see similar patterns from heat syncope and exhaustion in outpatient clinics to spikes in emergency room visits for heart failure and kidney injuries (Bujosa Mateu et al., 2024; Yezli et al., 2024).

The epidemiological record indicates that recent heat waves in the Gulf have measurable health impacts. Kuwaiti data show heat-attributable increases in CVD admissions, while Saudi data show large heat-attributable mortality among vulnerable pilgrims. These findings are consistent with global analyses projecting rising heat deaths: under warming scenarios, average annual heat-related mortality in MENA is projected to rise from ~2 per 100,000 today to over 100 per 100,000 by century's end. While predictions vary by assumptions, the message is clear: without adaptation, Gulf populations face increasing excess mortality and morbidity from more frequent and intense heat events (Alwadi et al., 2024; Bujosa Mateu et al., 2024; Hajat et al., 2023; Yezli et al., 2024).

3.3. Vulnerable Populations

The vulnerable population to heat wave includes migrant labor workers, old age people, young children, people with chronic illnesses, and people facing socioeconomic challenges.

3.3.1. Migrant laborers

Outdoor workers, especially in construction and agriculture, bear the brunt of Gulf heat. They often labor long hours in full sun, with heavy exertion and sometimes minimal shade. Evidence indicates this group suffers severe heat illness and mortality. For instance, a study of Nepalese migrants in Qatar found that heat stress significantly increased cardiac mortality in that cohort. Anecdotal reports and local health missions likewise document high rates of heat stroke, dehydration, and kidney injury among migrant workers in the Gulf. Contributing factors include lack of rest breaks,

limited access to cool drinking water, and sometimes inadequate workplace protections (Masood et al., 2024).

3.3.2. Elderly individuals

Age markedly worsens heat vulnerability. Older adults have less efficient sweat response, lower cardiac reserve, and blunted thirst, so they heat up faster (Arsad et al., 2022). Chronic conditions and medications (e.g. diuretics) compound dehydration. In heat waves, the elderly show dramatic spikes in heat-related hospitalizations. Notably, a recent review found that "water and electrolyte disturbances and acute kidney injury… are two leading causes of hospitalizations during heat waves in older adults". In practical terms, this means heat waves rapidly trigger renal failure and electrolyte crises in seniors. Cognitive impairment (dementia) can also impair self-care, so isolation during hot spells further risks dehydration or heatstroke in elders (Chapman, Johnson, et al., 2021; Schols et al., 2009).

3.3.3. Children and infants

Young children have higher surface-area-to-mass ratios and immature thermoregulation, making them less heat-tolerant. They depend on caregivers for adequate hydration and cooling. Heat can exacerbate pediatric illnesses (e.g. asthma exacerbations in hot, dusty air) and increase risk of dehydration or febrile convulsions (Schapiro et al., 2024; Xu et al., 2014). Large heat waves can strain pediatric services: globally, studies have shown spikes in pediatric emergency visits during severe heat, especially for infections and dehydration. In the Gulf, children in poor housing or attending outdoor nurseries/schools face similar risks (Al-Jawaldeh et al., 2022; Salam & Al-Khraif, 2020).

3.3.4. Individuals with chronic illnesses

People with pre-existing health problems fare poorly in extreme heat. Cardiovascular patients are at high risk of heart attacks and strokes when dehydrated or stressed by heat – as shown by heat-related surges in CVD admissions (Alwadi et al., 2024). Likewise, patients with chronic kidney disease suffer disproportionally: studies note that hemodialysis patients have higher mortality on hot days (Blum et al., 2024; Xi et al., 2024). Those with respiratory conditions (asthma, COPD) can have worsened symptoms in hot, humid air. Diabetes and obesity also impair heat dissipation. Moreover, any chronic disease that taxes the heart, lungs or kidneys amplifies heat risk (Bell et al., 2024; Brimicombe et al., 2024).

3.3.5. Socioeconomic and housing factors

Poverty and inadequate housing amplify heat exposure. Low-income migrant families in the Gulf may live in crowded dormitories or shacks with poor ventilation, thick concrete, or metal roofs that trap heat day and night. Many have limited or no air conditioning. These conditions greatly reduce the relief that night-time cooling normally provides. Thus, socioeconomic disadvantage creates a "double burden" of outdoor occupational heat and indoor chronic exposure. In urban areas, poor neighborhoods often have fewer trees and more heat-absorbing surfaces, raising ambient temperature (the "urban heat island" effect). Although formal studies in the Gulf are few, global evidence highlights that persons lacking air-conditioned shelter or urban green space suffer the worst outcomes in heat waves (El Mir, 2025; Salimi & Al-Ghamdi, 2020). In the Gulf region's rapidly urbanizing cities, planning and social interventions to protect these vulnerable groups will be essential to reduce heat-related illness (Al-Delaimy, 2020; Al Hurini et al., 2024; El Kenawy et al., 2024; Kjellstrom et al., 2022).

4. Occupational and Environmental Exposure in the Gulf Context

Outdoor and migrant workers in the GCC face extreme heat and combined environmental hazards. Construction laborers, oil-field workers, agricultural laborers and other outdoor workers are regularly exposed to daytime temperatures often exceeding 40-45 °C during summer, even with high humidity. These conditions have been linked to elevated risk of heat illness and injury. For example, a recent time-series study in Kuwait found that each 1-4 °C rise above 37 °C significantly increased work-related injuries, despite the country's legal summer midday break (Alahmad et al., 2023). In other words, calendar-based heat bans alone appear inadequate. Heat stroke, dehydration and heat exhaustion are commonly reported in field surveys of Gulf laborers, especially among un-acclimated migrants. Beyond acute heat illness, prolonged heat exposure also stresses renal function. A longitudinal study in Saudi Arabia found markers of kidney injury in over 10% of construction workers over the course of a single summer workday, with a substantial fraction of workers showing early signs of renal strain by season's end (Al-Bouwarthan et al., 2020). These findings echo the global recognition that repeated heat exposure and dehydration can precipitate AKI and contribute to chronic kidney disease among manual workers (e.g. sugar-cane cutters) (Chapman, Hess, et al., 2021). In the Gulf's oil and construction sectors, where labor is intense and shade limited, similar mechanisms likely operate (Al-Bouwarthan et al., 2020). Survey data from the region suggest that workers often lack adequate rest, hydration and education about heat risks. In one survey from Saudi Arabia, many workers reported symptoms of heat stress (dizziness, cramps) yet lacked effective cooling or rehydration protocols on site (Masood et al., 2024).

Environmental co-hazards amplify heat impacts in the Gulf. Frequent dust storms raise particulate pollution levels, which aggravate respiratory stress under high temperatures. Sea breezes along coastal cities provide some relief at night but often fail during stagnant heat waves, trapping heat and air pollutants over urban areas. UHIs are pronounced in many GCC cities, with inner-city

surfaces reaching up to 5-7 °C hotter than green spaces (Abulibdeh, 2021). Agricultural workers, though fewer in number, also contend with irrigation systems and machinery that further heat-load their environment. Ergonomic and safety hazards (e.g. heavy gear, lack of shade) intersect with heat: Masood et al. (2024) noted that studies in the Gulf have highlighted construction workers' heat stress as a serious physical hazard calling for protective measures (Masood et al., 2024). Furthermore, the evidence indicates that Gulf outdoor laborers face multiple concurrent exposures, extreme heat, high humidity, dust, and pollution – that drive heat-related morbidity. Given that these industries rely heavily on migrant labor, risks are compounded by gaps in social protections (Alahmad et al., 2023; Masood et al., 2024).

5. Adaptation, Preparedness, and Mitigation Strategies

GCC governments have begun to implement heat-health measures, though evaluations of their effectiveness remain sparse. All Gulf States enforce a summer "ban" on midday outdoor work (typically from late morning to early afternoon) to limit heat injury. However, recent evidence suggests this rule alone does not fully protect workers. Alahmad et al. (2023) demonstrated that even with the midday pause, Kuwait's extreme summer temperatures (often ≥40 °C) were associated with a 40-50% higher risk of on-the-job injuries than cooler days (Alahmad et al., 2023). This implies adaptation must go beyond fixed schedules. Some Gulf organizations are exploring mobile app–based heat warnings and continuous weather alerts, but peer-reviewed assessment of such systems in the region is lacking (Khamaj et al., 2021; Selvam & Al-Humairi, 2025).

Urban cooling strategies are emerging as important mitigations. Satellite analyses of Gulf cities show that increasing vegetation and using high-albedo building materials can reduce ambient temperatures. Abulibdeh (2021) found that in eight Gulf metropolises, green spaces were 1-5 °C cooler than surrounding urban areas, and bare land surfaces up to 7 °C hotter than vegetated zones

(Abulibdeh, 2021). In practice, municipalities are planting shade trees along streets and mandating cool roofs in new developments to combat the UHI. For example, Dubai and Abu Dhabi regulations now require certain reflectivity standards for pavements and rooftops (Alhammadi, 2023). Large cooling infrastructure projects – such as district cooling in commercial districts – are also under way (though formal studies of their public-health impact are not yet available) (Alotaibi & Nazari, 2023).

Early warning and health education campaigns have been piloted in some cities. Public messages during peak summer week's advice staying hydrated and avoiding outdoor activity. During the annual Hajj pilgrimage, Saudi health authorities routinely employ heat-prevention measures (misting tents, free water stations, shaded walkways), underscoring institutional awareness of heat risks. Community-driven interventions, such as laborer-focused hydration stations and shaded rest areas at construction sites, have been reported by NGOs, but systematic evaluation is again limited. The few studies that examine outcomes suggest room for improvement. For instance, even with warnings, migrant workers often lack access to water and rest breaks unless labor inspectors enforce compliance (Masood et al., 2024). While GCC governments and private groups are increasingly adopting heat-health plans and cooling measures, current evidence – including the persistent injury and illness patterns indicates that these adaptations need to be more comprehensive and rigorously implemented (Abulibdeh, 2021; Alahmad et al., 2023; Anwar et al., 2022).

6. Policy Recommendations

Current policies inadequately address the multifaceted impact of extreme heat on health and labor in the Gulf. Key gaps exist across public health, labor, housing, and urban planning sectors. First, health surveillance in GCC countries often fails to systematically capture heat-related illness data.

Unlike heat-vulnerable countries with heat-wave warning plans, Gulf nations lack integrated heat-health action plans that link meteorological alerts to medical preparedness. Establishing national heat-health action plans as recommended by WHO, it would allow health services to track heat morbidity, mobilize emergency response, and communicate risks during heat waves.

Labor protections also require strengthening. Although Gulf States legislate a midday work break, enforcement is inconsistent, and limits on cumulative daily hours are often poorly monitored. Migrant workers commonly live in crowded, poorly ventilated housing with only air-conditioned dormitories, yet labor codes do not mandate adequate cooling or rest facilities. Policymakers should align Gulf labor regulations with international standards (e.g. ILO heat stress guidelines) by guaranteeing shaded rest areas, regular hydration breaks, and maximum outdoor work hours during heat waves. Housing codes for workers' accommodations should require thermal insulation and ventilation standards to prevent indoor heat-related health effects, as recommended by studies of indoor heat stress.

Urban planning is another critical gap area. Rapid cities expansion in the GCC region often overlooks thermal considerations. Integrating "cool urban design" principles, such as preserving green space, using reflective building materials, and ensuring pedestrian shade should be mandated through updated building codes and zoning laws. For example, embedding green belts in residential developments and requiring tree-lined streets can reduce neighborhood heat burdens, as urban-climate research in the Gulf suggests (Abulibdeh, 2021). These measures would deliver long-term public health benefits by lowering ambient heat exposure for all citizens. To bridge these gaps, evidence-based reforms are needed. Governments should adopt formal heat health action plans with trigger-based warning systems, emergency healthcare protocols, and public education (WHO guidance). Labor laws must explicitly protect outdoor workers during extreme heat, with

enforceable penalties for violations. Housing regulations should guarantee that migrant and low-income populations have access to adequate cooling. Finally, urban resilience policies including heat-adaptive building standards and urban greening targets should be aligned with climate projections. All these policy steps should be guided by the growing evidence base on heat impacts in the Gulf (Masood et al., 2024) and best practices from global heat adaptation literature, ensuring that GCC reforms are both scientifically grounded and commensurate with international climate-health standards.

7. Future perspective of Heat wave and public health research

Looking ahead, urgent research is needed to inform GCC heat-health policy and protect vulnerable populations. First, enhanced epidemiological surveillance is critical. Baseline data on heat-related morbidity and mortality are sparse in many Gulf States; hospital and ambulance records should be systematically analyzed during heat episodes to quantify health impacts. Studies should particularly focus on high-risk groups including elderly residents, outdoor laborers, and migrants to uncover disparities. Equally important is gathering environmental data: fine-scale mapping of temperature and humidity exposures, together with occupational heat strain measurements, would clarify real-world risk scenarios (Alahmad et al., 2023).

Interdisciplinary research should link climate science to human health outcomes. For example, downscaled climate projections for the Gulf can be combined with epidemiological models to predict future disease burdens (e.g. heat stress–related kidney injury or cardiovascular events) under various warming scenarios. Socioeconomic research is also needed to assess the effectiveness of adaptation measures. Policy analysts should evaluate ongoing interventions – from early warning systems to labor regulations to determine which strategies most effectively reduce heat illness. The Gulf's large expatriate population calls for studies on equity and access: research

must examine how factors like legal status, language barriers, and housing conditions modulate heat vulnerability. Finally, capacity building and regional collaboration will be key. Establishing a Gulf-wide heat-health research network could facilitate data sharing and joint studies across Saudi Arabia, UAE, Qatar, Bahrain, Kuwait, and Oman. Incorporating heat-health modules into existing surveillance (e.g. infectious disease reporting or occupational injury databases) would yield valuable data with minimal new infrastructure. Longitudinal cohort studies of workers and climate-sensitive populations in the region would illuminate chronic effects of repeated heat exposure. In sum, future research priorities include robust surveillance systems, targeted exposure assessment, and integrated climate-health modeling, all tailored to the Gulf context. These interdisciplinary efforts will provide the evidence base needed to protect public health as the region faces unprecedented warming.

8. Conclusion

The GCC countries are experiencing an unprecedented escalation of extreme heat events, driven by global climate change and exacerbated by rapid urbanization. Over recent decades, mean temperatures and humidity levels across the Arabian Peninsula have risen significantly, leading to more frequent, intense, and prolonged heat waves. This warming trend projected to continue under all emissions scenarios poses severe public health threats, particularly as Gulf cities contend with pronounced UHIs that amplify ambient heat by up to 6-7 °C in dense districts.

Heat exposure in the GCC has been linked to a spectrum of adverse health outcomes. Physiological studies demonstrate that high wet-bulb temperatures impair the body's thermoregulatory mechanisms, precipitating heat exhaustion, heatstroke, and multiorgan dysfunction. Epidemiological analyses reveal substantial increases in cardiovascular and renal hospitalizations during heat waves Kuwait alone reports that nearly 8% of CVD admissions in hot periods are heat-

attributable while pilgrims in Makkah exhibited heat-related mortality affecting over 70% of deaths in peak seasons. Outdoor laborers, who perform strenuous work under extreme heat, face particularly high risk. Studies in Saudi Arabia and Kuwait show early markers of acute kidney injury developing over single workdays and a strong correlation between ambient heat and occupational injuries. Compounded by limited enforcement of midday work bans and insufficient on-site hydration and shade, these populations remain highly vulnerable.

While GCC governments have initiated adaptation measures such as midday work restrictions, early warning systems, and urban greening pilots, the persistence of heat-related morbidity and mortality indicates that current strategies are insufficiently comprehensive or enforced. Policy gaps in health surveillance, labor protection, housing standards, and urban planning must be addressed. Adoption of WHO heat–health action plans, alignment of labor laws with ILO heat-stress guidelines, and integration of cool-urban design principles into building codes are essential next steps. Future research should focus on high resolution exposure assessment, robust epidemiological surveillance, and evaluation of adaptation interventions. Interdisciplinary collaboration linking climate modeling, public health, occupational safety, and urban design will enable predictive health-impact modeling and targeted policy formulation. A Gulf-wide heat-health research network could foster data sharing and harmonize methodologies, while longitudinal cohort studies of migrant and local populations would clarify chronic effects of repeated heat exposure.

Statements and Declarations

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Conflict of Interest

The author(s) have no conflict of interest to declare.

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