

ECONOMIST
ENTERPRISE

Beating the heat: Protecting kidney health in a warming world



Supported by



Contents

- 4 About this report**
- 6 Executive summary**
- 11 The kidney health implications of rising temperatures**
- 11 Heat: A health challenge that isn't going away**
- 13 Kidney injury and disease, and where heat fits in**
 - Prevalence and trends
 - How does heat fit into this picture?
- 17 Vulnerable groups in the general population**
 - Older and young people
 - People living with pre-existing conditions: CKD, cardiovascular disease and diabetes
 - People taking certain medicines or foods
 - Women, men and socio-economic status
 - Workers
- 27 The policy response: The time is now**
- 27 International actions and multi-sectoral domestic government initiatives**
 - International responses
 - Ownership: The importance of domestic action
- 30 The role of public health authorities and health system workers**
 - Awareness
 - Clinical guidelines
 - Health workforce
 - The potential for targeted screening

33 The role of those shaping the workplace: Health and safety regulators, companies, workers and NGOs

Harnessing government regulation

The need for a broader coalition

Hearts and minds

36 The role of the scientific and research community

Scientific and evidence gaps in the heat-kidney nexus revealed by our research

Wrestling with the definition of heat-related kidney diseases: The need for an overarching framework

Detection and biomarkers

39 Conclusion and policy takeaways

41 References

About this report

In 2025, Economist Enterprise, then known as Economist Impact, examined how societies need to adapt to climate change and protect those whose health it endangers, particularly people living with cardiovascular, renal and metabolic disorders.¹ In 2026, our work has focused on how heat affects kidney health, moving from a broad understanding of the challenge towards more focused and actionable solutions. By bringing healthcare professionals, policymakers, researchers and public health experts together, it aims to turn growing evidence into meaningful action.



Beating the heat: Protecting kidney health in a warming world is a report produced by Economist Enterprise and supported by Bayer. It examines how rising temperatures and extreme heat affect kidney health, with particular attention to acute kidney injury and chronic kidney disease—including chronic kidney disease of non-traditional or unknown aetiology.

The report explores the pathways through which heat stress can become kidney stress, the scale and distribution of the emerging health burden, and the people most at risk. In addition, the report assesses the policy responses required to protect kidney health in a warming world. It highlights steps by different actors, including whole-of-government initiatives and action by health systems, public health authorities, stakeholders in employment relations and researchers, all of which can collectively reduce heat's negative impacts on kidney health.

The research comprised a rapid and targeted literature review, in-depth expert interviews, and a virtual scientific advisory council that convened on June 23rd 2026, whereby Economist Enterprise prepared a set of “Emerging statements” based on widespread agreement, if not always consensus, by the council. The council brought together nephrologists, climate and health researchers, occupational health specialists, scientists, and public health experts from Africa, Asia, Europe, Latin America and North America.

Economist Enterprise would like to thank the following scientific advisory council members who contributed insights to the research (in alphabetical order):

- **Shuchi Anand**, associate dean for global health and professor of medicine, UC Davis Health, US
- **Ben Caplin**, professor of nephrology, University College London, UK
- **Guillermo Garcia-Garcia**, research professor, University of Guadalajara Health Sciences Center; former director and founder, Department of Nephrology, Hospital Civil de Guadalajara, Mexico
- **Jason R Glaser**, founder and CEO, La Isla Network, US
- **Kithsiri B Jayasekara**, professor in medical laboratory science, Department of Medical Laboratory Science, Faculty of Allied Health Sciences, General Sir John Kotelawala Defence University, Sri Lanka
- **Vivekanand Jha**, executive director, The George Institute for Global Health, India
- **José Moura-Neto**, nephrologist and president, Brazilian Society of Nephrology, Brazil
- **José Vicente Sánchez Polo**, nephrologist and head of the renal division, General Hospital, Guatemalan Social Security Institute, Guatemala; president, Latin-American Society of Nephrology (SLANH)
- **Ifeoma Ulasi**, nephrologist and professor of medicine, University of Nigeria, Nigeria
- **Eranga Wijewickrama**, professor in medicine and consultant nephrologist, University of Colombo, Sri Lanka

We would also like to thank these experts, who provided insights through in-depth interviews:

- **Kristie Ebi**, professor, Center for Health and the Global Environment at the University of Washington, US
- **William Martinez**, occupational health expert, La Isla Network, Nicaragua
- **Carlos M Orantes Navarro**, nephrologist and research scientist, NefroCenter El Salvador
- **Agnes Soares da Silva***, director, Department of Environmental Health Surveillance and Workers' Health at the Secretariat of Health and Environment Surveillance, Ministry of Health, Brazil. *For identification purposes only, the views reflected here are personal.

All advisory council members and other experts participated voluntarily and received no financial compensation for their contributions to this independent research.

This research was led by Elizabeth Sukkar, senior research manager in policy and insights at Economist Enterprise. Research, interviews and advisory council activities were undertaken by Alcir Santos Neto, Radha Raghupathy and Elizabeth Sukkar. The report was written by Paul Kiestra and Elizabeth Sukkar. Fact-checking support was provided by Dhruv Gupta and copy editing by Amanda Simms. The findings and views expressed in the report do not necessarily reflect the views of the supporting organisation. The report was finalised in September 2026.

Executive summary

Extreme heat is becoming more common and intense, with hot spells lasting longer as the climate warms. Even if countries meet their current pledges to cut greenhouse gas emissions, global temperatures are projected to reach 2.3-2.5°C above pre-industrial levels by 2100.

Rising temperatures pose a growing threat to human health. Prolonged or intense heat can strain several of the body's systems, raising the risk of illness and death. Understanding who is most at risk, and how heat affects their health, will become more pressing as the world warms.

In 2025, Economist Enterprise examined how societies can adapt to the effects of climate change, including the consequences for people living with cardiovascular, renal and metabolic diseases. This report narrows the lens to one part of that challenge: the effects of extreme heat on kidney health and disease, thereby moving from a broad understanding of the challenge towards more focused and actionable solutions. By bringing healthcare professionals, policymakers, researchers and public health experts together, it aims to turn growing evidence into meaningful action.

With climate change bringing warmer average temperatures and, especially, an increase in the frequency of heatwaves, instances of people experiencing heat stress inevitably increase. This stress can affect human kidneys, which may lead to temporary or permanent damage. Rising heat is happening amid an already high burden of kidney disease. Nearly one in seven people worldwide

live with chronic kidney disease (CKD), just one of several conditions that affect the kidneys.

This report examines the renal challenges of rising temperatures, with a focus on CKD and acute kidney injury (AKI). It also discusses who is most at risk, what the science is currently telling us (including the gaps in that message), as well as policy options available now to reduce their potential health and societal burden. Importantly, this report argues for the need for an overarching **heat-kidney framework**, which looks at how heat affects that organ's health among a wide range of at-risk groups, beyond those that have been historically studied in the past.

The key findings include:

Global warming is increasing not just average temperatures but also the frequency of episodes of extreme heat. Already, climate change is responsible for an estimated 84% of heatwaves worldwide and the proportion of the global population exposed to extreme heat stress for at least one day per year has risen to 21.9%, up from 15.9% in the 1970s. Estimated future increases in average temperature could nearly double again the proportion of the population affected in this way. People living in regions where such stress was rare before will start to experience it.

Heat is crashing into an already substantial burden of kidney disease. According to Global Burden of Disease (GBD) data from 2023, between 743m and 843m people are living with CKD.

The GBD also estimates that the condition is now the ninth-leading cause of mortality globally, accounting for between 1.3m and 1.7m deaths worldwide. By 2040, it is expected to be the fifth-leading cause of death. Other research estimates that around 41m people per year suffer from AKI. Any new multiplier of existing kidney risks, such as heat, would therefore be a substantial public health worry, affecting individuals, health systems, societies and economies. According to one expert, Vivekanand Jha, executive director of The George Institute for Global Health in India: “Policymakers should view the kidneys as a barometer for the overall impact of heat on human health, seeing them as the canary in the coal mine.”

This collision could have important public health consequences. At an individual level, heat stress can put pressure on kidneys, which could cause AKI, an often symptomless condition, and if repeated or unmanaged, could increase the risk of this progressing to CKD. Data from hospital admissions during heatwaves show that this tendency has an effect on populations in countries at every level of development. In the UK, for example, an analysis found that for every increase of 1°C above 25°C, the odds of an AKI incident seeking admission rose by 3.8%. Meanwhile, a Chinese study found that repeated heatwave exposure increased the likelihood of rapid kidney decline. It is hard to tease out the effects of heat-related kidney disease in national, let alone international, data as yet. It is, though, becoming apparent in some places.



The impacts are global but unequal as certain groups are particularly at risk of heat-related kidney damage. While high heat puts stress on everyone's kidneys, some parts of the population statistically tend to suffer more health damage. Studies from heatwaves indicate that older people, especially those over 80, fall into this category, although in some research children under five are also affected more often than the general population. People living with existing kidney ailments, especially CKD, are also in greater danger. South Korean research found that estimated glomerular filtration rate (eGFR) declined among people with CKD with each degree of warming above 25°C. So too are those living with other NCDs, especially diabetes and heart disease, both of which appear to be biologically connected with kidney disease.

Workers are at risk of heat-related kidney damage. Depending on their employment environment, workers are at risk of developing AKI, subclinical kidney disease or longer lasting CKD as a result of heat stress. Workers have been the most studied at-risk group for heat-related kidney diseases, but there is a need to broaden our understanding of at-risk groups within an overarching heat-kidney framework. For the last two decades, a new form of CKD appeared in workers living in Central America and South Asia, where heat is a likely part of causation. Agricultural workers have been the sentinel population of study for this new condition, described as chronic kidney disease of unknown or non-traditional aetiology (CKDu/CKDnt). In some areas, such as Uddanam, India, and parts of Northwest Nicaragua, the prevalence of CKDu has reached 14% among rural men. Deaths in young male labourers near Chichigalpa, Nicaragua, have led to the community being called the Island of Widows. In the past decade, nearly 45% of all male deaths in this area were due to CKD, including 75% of male deaths between 35 and 55 years. Extensive debate about its cause ensued but the growing consensus is that heat exposure plays an important part. As one study put it, associations between high heat exposure and CKDu “are strong, consistent, and specific”. In particular, those who work in great heat, with poor conditions or ability to take breaks, seem the most affected.

Other groups may face greater risk from heat, but evidence is lacking. Women remain understudied in kidney research, particularly when it comes to sex differences in kidney structure, function and health. Indeed, different academic publications do not even agree on which gender is more likely to proceed to late stage kidney disease, although most agree those more likely to die are men. Amid this uncertainty, too few studies look at these sex-specific differences. Doing so will be important for understanding how heat potentially adds another layer of impact onto female kidney health. People living in low-resource countries face a greater risk of heat stress because they often have less access to cooling and healthcare. CKD risks may be particularly acute in low- and middle-income countries, where it remains underdiagnosed and, of particular relevance to this study, average temperatures are higher. Compounding the difficulty in these countries, low-resource weak health systems provide limited access to testing and diagnostic services making the disease harder to detect and treat.

There are several areas where society can take meaningful steps now on heat and kidney health.

The science and policy actions most likely to have a positive effect fall into four broad categories:

- **All-of-government actions supported by international bodies.** Countries and cities need to be prepared for periods for both acute heat events and prolonged periods of high heat exposure. National and local heat plans allow the deployment of prevention initiatives, as well as making a coordinated and well-informed response possible when heatwaves do occur. Indeed, Brazil's new data portal, which combines temperature data with other key local information such as water availability and area wealth levels, can give five days of warning to local authorities to get ready. Heatwave early warning systems can also alert officials and the general public about coming high temperatures, allowing them to prepare and act wisely. International bodies, meanwhile, have an awareness-raising role, such as through the WHO's 2025 resolution to promote kidney health, strengthen prevention and control of the disease, and help disseminate best practice.
- **Strengthening health systems' ability to detect and respond.** Awareness of kidney disease, including how heat can increase incidence and worsen outcomes, is poor among the general public and, perhaps more worrying, among clinicians. Clinical guidelines are few and far between. However, change may be occurring with KDIGO's proposed 2026 AKI guidelines instructing clinicians when heat is an appropriate likely cause of such events. More generally, over half of countries lack sufficient nephrologists. Doctors and nurses in primary care often lack the necessary information or training to pick up the slack, and efforts to use other professionals for parts of the task are few. In a warming world, these areas need more attention and resources, particularly how best to detect AKI in vulnerable people at risk of the disease progressing, including investing in point-of-care testing in low-resource settings. Finally, health systems may want to consider screening individuals among high-risk groups. This has proved cost-effective in high-income and some middle-income countries for those with common CKD co-morbidities and people aged over 55.
- **Workplace action.** There is a need to protect outdoor, indoor, formal and informal workers from heat's effect on their kidney health through locally appropriate measures. Given the links between kidney injury and heat stress within certain occupations, appropriate health and safety regulations are a necessary foundation if that epidemic is to be addressed. Currently available guidance and rules, though, tend to be too broad: one expert noted that the most respected ones would prevent any outdoor work in tropical countries. Accordingly, workplaces require a broad coalition of employers, employees and outside experts to adopt rules and processes appropriate for their particular circumstances. Success will require cooperation, but also education to show all parties how they benefit from these actions. To give just one example, a study in Nicaragua found that the increased productivity resulting from a rest-shade-hydration-sanitation programme paid for the intervention within three years. Thereafter it had a positive return on investment.

- **The scientific and research community.**

Researchers should address the priority scientific gaps, including clarifying progression from AKI to CKD, and improving research for under-studied populations such as women and those living in low-resource settings. Other areas include finding effective uses for existing biomarkers for workers in the field to allow early detection to prevent AKI or other kidney damage. They are unlikely to be regularly monitored for kidney function. An important, broader aim is to come up with a

coherent and comprehensive conceptualisation of heat's effects across all areas of kidney health (see *Box 1*). This could include developing a better understanding of the quantitative effects of heat on those facing different kinds of kidney risk. Research funders, meanwhile, should prioritise studies that answer policy and implementation questions, including which populations need early detection and heat-risk thresholds as nations apply different definitions for heatwaves based on local conditions.

BOX 1**Emerging statements from the heat-kidney scientific advisory council: these complement the report's broader findings**

The advisory council met virtually on June 23rd 2026 to discuss the effects of heat on kidney health. Although views differed on some topics, several themes emerged repeatedly during the discussion. Economist Enterprise has summarised these areas of broad agreement. These complement the report's broader findings.

**SCIENCE**

1. Heat exposure **contributes** to kidney injury and disease, making the kidneys a sensitive and early indicator of the wider effects of heat on human health.
2. A **heat-kidney framework** is needed to move beyond diagnosis by exclusion and instead recognise heat exposure and the full spectrum of heat-related kidney injury.
3. The greatest burden of heat-related kidney injury will be on vulnerable people and those living with **pre-existing diseases** such as diabetes, kidney disease and cardiovascular disease (CVD).
4. There is associative evidence in certain **occupational settings and geographies**, (eg, among workers in Central America and Asia) linking the impacts of heat stress on kidney injury and disease, described as CKD unknown aetiology/CKD of non-traditional cause.

**THE POLICY RESPONSE**

5. **Awareness** of heat as a risk factor for kidney disease must improve, as it remains poorly recognised.
6. **Policymakers should act now** to address heat-related kidney risk rather than awaiting more detailed information on how heat and kidneys interact. Existing evidence already supports practical measures such as cooling strategies, access to water, shade and rest, heat alerts, worker protections, and education.
7. **Policy responses should be multisectoral**, combining health-system awareness and early detection with workplace protections, community education and leadership from clinicians, public-health actors and professional societies.
8. **Heat-risk policy should not rely on one-size-fits-all guidance**; interventions need to be adapted to specific workplaces, indoor and outdoor settings, workloads and exposure patterns, then evaluated for implementation and impact.

BOX 2

Summary of actions for key stakeholders



At-risk individuals: people need to understand the extent to which they are vulnerable to kidney disease and how exposure to high levels of heat might exacerbate that. Prevention works best when those at risk are on board.



Healthcare systems: awareness of CKD, its risks and the possible effects of heat on patients needs to improve among healthcare professionals. Using this better knowledge as a foundation, health systems should engage in appropriate individual patient education as well as opportunistic diagnosis interventions where merited.



Public health: officials in this field should consider what population-wide interventions might be useful in their jurisdictions, in particular appropriate education initiatives (about kidney health and the health dangers of heat), as well as possible cost-effective targeted screening programmes.



National and local governments: beyond healthcare programmes and ministries, governments need to develop plans to prepare for heatwaves and climate change more generally. Any strategy must consider how such events will increase the burden of specific diseases, including those affecting the kidney. Officials also need to create regulations that can reduce heat's effect on health across various fields, going from employment law to building regulation.



Employers and employees: these groups should work together, bringing in experts where helpful, to design workplaces and work practices that minimise the heat dangers arising from their employment activities.



Academics and researchers: these should address the many scientific gaps, discussed elsewhere, in our current knowledge of how heat and kidney health interact. Funders should consider ways to support these endeavours, including prioritising studies that answer practical policy questions, such as which populations need early detection and what heat-risk thresholds to use, as countries define heatwaves differently according to local conditions.

SECTION 1

The kidney health implications of rising temperatures

1.1 Heat: A health challenge that isn't going away

STATEMENT NO 1

Heat exposure **contributes** to kidney injury and disease, making the kidneys a sensitive and early indicator of the wider effects of heat on human health.

Climate change is making extreme heat events more common, more intense and longer lasting.² Even if countries meet today's climate pledges, the world is on course for much higher temperatures by the end of the century. Estimates place this at 2.3°C and 2.5°C above pre-industrial levels, with 1.5°C expected within the next decade.³

Heat is not just an environmental concern, it is an all-of-society one. Crucially, it is a growing public health challenge, especially for vulnerable people, including, but not limited to, older people and those living with certain non-communicable diseases (NCDs), which includes cardiovascular, respiratory and kidney conditions.⁴ There are robust associations between heat exposure and adverse health outcomes.⁵

Rising temperatures bring a range of diverse health challenges. As Vivekanand Jha—executive director of the George Institute for Global Health India and chair of Global Kidney Health at Imperial College London—puts it, medically, “the entire world's global

population is at risk of heat.” Indeed, GBD figures estimate that 308,000 people died from excess heat in 2019, spread across every continent.⁶

Heat must be looked at in two ways: the effects of a gradual warming world and the rise of extreme heat events known as heatwaves, which have different definitions depending on where people live.

The Lancet Countdown on Climate Health's 2025 report estimates that currently 84% of heatwaves worldwide would not have occurred without climate change.⁷ The European Centre for Medium-Range Weather Forecasts finds that globally, “the spatial footprint of hazardous heat stress has expanded, exposing previously unaffected regions, [including] ... where it has historically not been experienced.”⁸ Looking ahead, other researchers project that, if average global temperatures rise by 2°C, the share of the world experiencing frequent extreme heat will grow from 23% in 2010 to 41% by 2050.⁹ A global study found that the proportion of the world's population exposed to strong heat stress for at least 30 days a year rose from 73.2% in the 1970s to 85.1% in 2015-24, while the proportion exposed to extreme heat stress for at least one day rose from 15.9% to 21.9% (see *Table 1*).¹⁰

The kidneys are particularly vulnerable to the effects of heat (see *Figure 1 for pathogenesis*). As Professor Jha says: “Policy-makers should view the kidneys as a barometer for the overall impact of heat on human health, seeing them as the canary in the coal mine.” Dr Shuchi Anand, a nephrologist and associate dean for Global Health at the University of California Davis, adds: “It is not just about extreme levels of

heat that affect kidney health. We need to act to prevent injury to kidneys from [moderate heat] ... Recognising heat as a risk factor for kidney disease would be a major accomplishment in nephrology and public health."

Understanding how rising temperatures shape kidney health is now essential for protecting lives through better planning, prevention, detection and strengthening the resilience of individuals and communities.

This study aims to shed light on this incompletely understood area, while encouraging actions expected to be useful even amid current uncertainties.



"Policy-makers should view the kidneys as a barometer for the overall impact of heat on human health, seeing them as the canary in the coal mine."

Vivekanand Jha, executive director of the George Institute for Global Health India

It focuses on the relationship between heat and two specific kidney disorders for which sufficient evidence exists.

Acute kidney injury (AKI): the US National Kidney Foundation describes AKI as a state where "kidneys are suddenly not able to filter waste products from the blood. This can happen within a few hours or a few days. For most people, AKI develops within 48 hours, but sometimes it can take as long as 7 days."¹¹ The 2026 draft guidelines of KDIGO (a global non-government organisation [NGO] developing evidence-based clinical practice guidelines in kidney disease) recommend diagnosis through one or more of an increased presence in the blood of serum creatinine (a waste product of muscles), an increased presence of serum cystatin C (a protein usually cleared by the kidney), and low levels of urine output.¹² AKI can result in a dangerous waste buildup in the body. The condition can arise from multiple potential causes, acting alone or in conjunction. Although AKI can be treated, having had an episode increases the affected individual's risk of developing CKD.¹³

Chronic kidney disease (CKD): CKD, which was only formally defined in 2002, is a heterogeneous disease with many different causes, including diabetes, infections and autoimmune diseases.^{14,15} The US National Kidney Foundation describes CKD as a condition where "the kidneys have become damaged over time (for at least 3 months) and have a hard time doing all their ... jobs." These tasks include cleaning the blood, as well as maintaining healthy blood pressure and important mineral balances. It is a slow-developing condition with few initial symptoms, which makes detection a challenge.¹⁶ CKD's severity is measured in five stages, with these defined in part by the extent of reduced levels of eGFR (put simply, a measure of the ability of the kidneys to clean the blood). A decline in eGFR to below 60 mL/min/1.73 m² indicates CKD. Staging is also affected by the albumin-to-creatinine ratio (which measures albumin in the blood, a protein usually cleared by the kidneys). Management depends on the stage of kidney disease. At stage 5, also known as end-stage kidney disease, most patients need regular dialysis, which can be costly and may reduce quality of life.¹⁷

Table 1: Percentage of global population exposed to heat stress¹⁸, 1970s vs 2015-24

Heat stress category	Duration threshold	Population exposed in the 1970s	Population exposed in 2015-24	Rising
Strong heat stress	At least 1 day	94.5%	96.7%	▲
	At least 30 days	73.2%	85.1%	▲
	At least 90 days	55.4%	69.5%	▲
Very strong heat stress	At least 1 day	63.0%	76.6%	▲
	At least 30 days	37.1%	52.6%	▲
	At least 90 days	20.8%	32.4%	▲
Extreme heat stress	At least 1 day	15.9%	21.9%	▲
	At least 30 days	2.1%	3.9%	▲
	At least 90 days	0.3%	1.0%	▲

Source: Emerton R, Nicolas J, Lombardi A, et al. Global heat stress intensification and its expanding footprint on the human population. *Nature Climate Change* [Internet]. June 22 2026;16(8):989–96. Available from: <https://www.nature.com/articles/s41558-026-02670-5>. Heat stress is the net heat load experienced by an individual, accounting for environmental and personal factors. It reflects the combined effects of air temperature, humidity, wind and solar radiation, as well as how the human body responds to those conditions. In this study, heat stress is measured using the Universal Thermal Climate Index and expressed as a “feels-like” temperature.

1.2 Kidney injury and disease, and where heat fits in

Prevalence and trends

Kidney disease is so common globally that in May 2025 the World Health Organization (WHO) adopted a resolution to promote kidney health.¹⁹ This follows up on a World Health Assembly resolution in February 2025 that advocated better prevention and control of the disease, and the dissemination of best practice.²⁰

According to the latest GBD data, in 2023, between 743m and 843m adults worldwide were living with CKD, with a best central estimate of 788m, a prevalence rate of 14.2%, or around one in seven people.²¹ By this metric, it is in the same ballpark as heart disease and diabetes, conditions that have a bidirectional relationship with kidney health.²² CKD is also now the ninth-leading cause of death worldwide and expected to become the fifth biggest by 2040.²³

788m



In 2023, between 743m and 843m adults worldwide were living with CKD, with a best central estimate of 788m, a prevalence rate of 14.2%.

Data on AKI are less robust, in part because a common definition was not proposed until 2012.²⁴ Moreover, that definition requires a comparison with the creatinine level baseline of the affected individual, which differs from person to person.²⁵ Even so, the problem appears to be widespread. Worldwide, the likely annual global AKI incidence is around 40.8m cases, finds a recent pooled calculation from 88 studies.²⁶ That said, uncertainty in the data—especially information from developing countries—was such that the authors could say with 95% confidence that it fell roughly between 30m and 54m.



“There is general consensus that heat-exacerbated kidney disease is a major population health problem.”

Ben Caplin, professor of nephrology at University College London

Longer trend data do not yet exist for AKI, but are available for CKD.²⁷ In 1990, the age-standardised prevalence rate for CKD was 13.7%, rising to 13.9% over the next three decades. From 2020 to 2023, the number rose to 14.2%.²⁸

How does heat fit into this picture?

At the individual level, says Professor Ebi of the Center for Health and the Global Environment at the University of Washington, “the science of thermal physiology is robust and very clear. For some people, in high temperatures, there’s no question about the adverse impact on their kidneys.” (See Box 3)

On the population level, the GBD study estimates that the burden (age-standardised disability-adjusted life years (DALYs) of CKD attributable to non-optimal temperatures, which includes both hot and cold, is around 4.4%. It is much lower than other population attributable factors (PAF) but as the world warms, this metric will matter as policymakers issue heat alerts and heat action plans (see section 2). Overall, the leading contributors to age-standardised DALYs from CKD (measured by PAF) are high fasting plasma glucose (31.9%), high systolic blood pressure (24.5%), high body mass index (23.5%) and diet (17.6%).²⁹

When non-optimal temperatures are analysed in detail, the attributable CKD DALYs and deaths due to high heat (as a PAF) rose from 71,000 DALYs in 1990 to 295,000 DALYs in 2019 while deaths increased from 2,000 to 11,000, respectively.³⁰ Overall, heat as a population attribution factor rose from 0.38% to 1% of deaths. The PAF for low temperatures has declined over this period.

Other diseases that have a bidirectional relationship with CKD have seen even more marked increases. For diabetes DALYs with heat as a PAF rose from 193,000 in 1990 to 734,000 in 2019. The PAF of diabetes mortality grew from 1.19% to 2.21% of

deaths.³¹ Presumably, there was a knock-on effect on CKD, but the extent is impossible to estimate.

Indeed, while the GBD figures are the best available estimates, they are not exact, which explains the wide range of cases and deaths within the 95% certainty range. The organisation is aware of the difficulties arising from the under-reporting of certain conditions, including CKD, by health systems, especially low-resource ones. Accordingly, it looks at a wide range of sources as possible and uses advanced statistical methods (notably spatiotemporal Gaussian processes and cause-of-death ensemble modelling).³² While this still might lead to under-reporting, the opposite is also true. A recent comparison of GBD figures, derived using modelling, and 14 reportable diseases in China found that the figures from the Chinese Center for Disease Control and Prevention were much lower.³³ In short, these are the best global figures currently available but should be seen as estimates.

This relatively modest global estimate should not obscure the risks to people living with elevated risks (see Section 1.3). “There is general consensus that heat-exacerbated kidney disease is a major population health problem,” said Ben Caplin, professor of nephrology at University College London.

When the data are disaggregated by region, the burden of CKD attributable to high temperatures has increased fastest in places with warmer climates and lower levels of socioeconomic development. Tropical and subtropical regions, as well as low- and low-middle socio-demographic index (SDI) countries, recorded the steepest increases, while Africa experienced the largest continental rise in heat-attributable CKD mortality, followed by Asia and Oceania.^{34,35} Teasing out the contribution of heat and poverty to this growth in prevalence, though, is not straightforward.

BOX 3

How heat stress becomes kidney stress

“It takes a while for our core body temperatures to rise,” says Professor Kristie Ebi of the University of Washington. In a hot environment, humans have potential coping mechanisms, including physiological (for example, sweating) and behavioural (for example, seeking a cool drink in the shade). When these are insufficient to address increasing heat accumulation in the body, then the core body temperature starts to rise—a process typically measured in hours rather than minutes.³⁶

To greatly simplify a complex set of processes, certain physiological responses to rising core body temperatures affect the kidney (see *Figure 1*). First, the body activates the sympathetic nervous system, leading to constriction of the kidney’s blood vessels and reduced flow through them.³⁷ Simultaneously, so-called peripheral vasodilation promotes perspiration and redirects blood flow from internal organs to the skin to take advantage of the cooling properties of sweat. Absent an intake of water and minerals at this stage, dehydration and a further drop in kidney blood flow can occur.^{38,39}

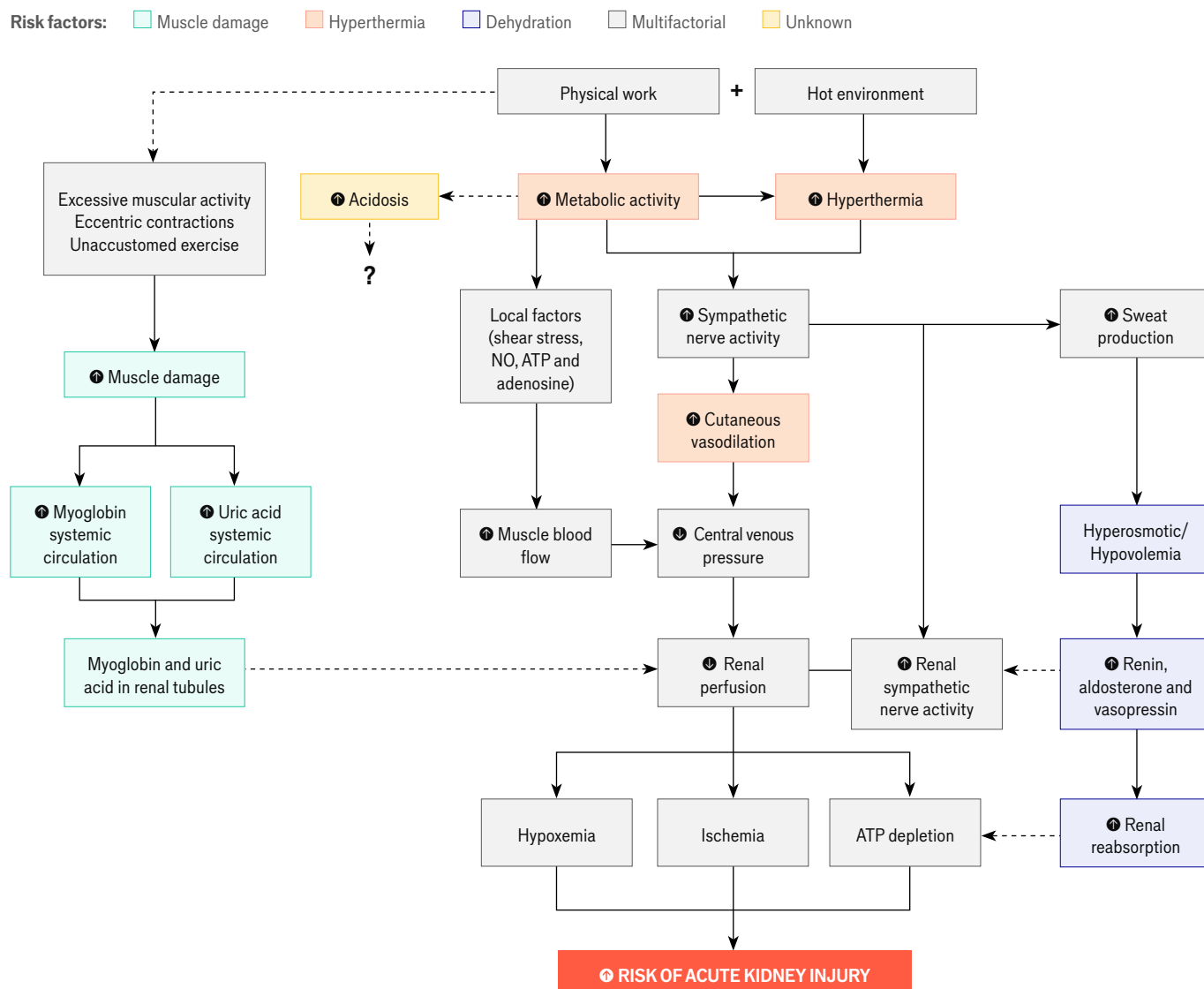
The body then attempts to adjust to this reduced flow by activating the so-called vasopressin and renin-angiotensin-aldosterone systems. While this promotes water reabsorption, other effects—such as *inter alia*, reduced oxygen delivery to the kidneys and increased urinary concentration—create a toxic environment that can lead to structural kidney damage.^{40,41} Another simultaneous danger in this situation is heat-induced rhabdomyolysis (rapid muscle breakdown). As muscle fibres succumb to heat stress, they give off compounds such as creatine kinase, lactate dehydrogenase, myoglobin and, sometimes, uric acid. Once circulating in the body, these too can damage renal tubules, induce further kidney injury and diminish blood flow to that organ further still.^{42,43}

When the accumulated stress and damage become too great, AKI can result, leaving kidneys unable to clear waste products from the blood.⁴⁴ Although this can be managed, it can also lead to CKD. While this process is not fully understood, the risk increases with the severity and frequency of AKI episodes a person experiences.⁴⁵

Although these biological pathways explain how heat can damage the kidneys at the individual level, the epidemiological evidence presented in this report indicates that these effects also translate into a measurable population health burden.



Figure 1: The sequence of events that lead to an increased risk of acute kidney injury during physical work and heat stress⁴⁶



Source: Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>

Note: the sequence of events that lead to an increased risk of acute kidney injury during physical work and heat stress. Solid arrows indicate necessary “cause and effect” relationships between the events. Dashed arrows indicate possible relationships, where the downstream event may or may not happen, depending on the levels of impact of the upstream event. The question mark indicates the effect is unclear and research is needed.

1.3 Vulnerable groups in the general population

Heat can harm kidney health in many ways, but the risks are not shared equally. Some people are more vulnerable because of their age, renal reserve or underlying health conditions such as diabetes and CKD, their working conditions or even some medicines, which can reduce the body's ability to cope with heat.⁴⁷ Some possible at-risk groups, such as women and those of lower socio-economic status, have been understudied. This section examines some of the key groups at risk from elevated heat, especially heatwaves (see Figure 2).

Much of our understanding of heat-related kidney risk comes from looking at the impact of heatwaves on hospital emergency admissions for kidney problems. The discussion requires nuance, though. Seeing any one risk in isolation tells only a part of the story. José Moura-Neto, a nephrologist and president of the Brazilian Society of Nephrology, explains that to describe “the relationship between heat and kidney health, the word that comes to mind is amplification” of any existing risk, of which a given individual may face several.

Moreover, while patients admitted during heatwaves are more likely to share certain characteristics,



A recent modelling study found that those aged 65 and older account for most heatwave-related increases in emergency visits and deaths amid climate change.

studies also show exceptions to most generalisations. The explanation for this diversity, explains Dr Anand, are variations in exposure.

With this in mind, the data point to certain major risk categories.

STATEMENTS NO 2 AND 3

A heat-kidney framework is needed to move beyond diagnosis by exclusion and instead recognise heat exposure and the full spectrum of heat-related kidney injury.

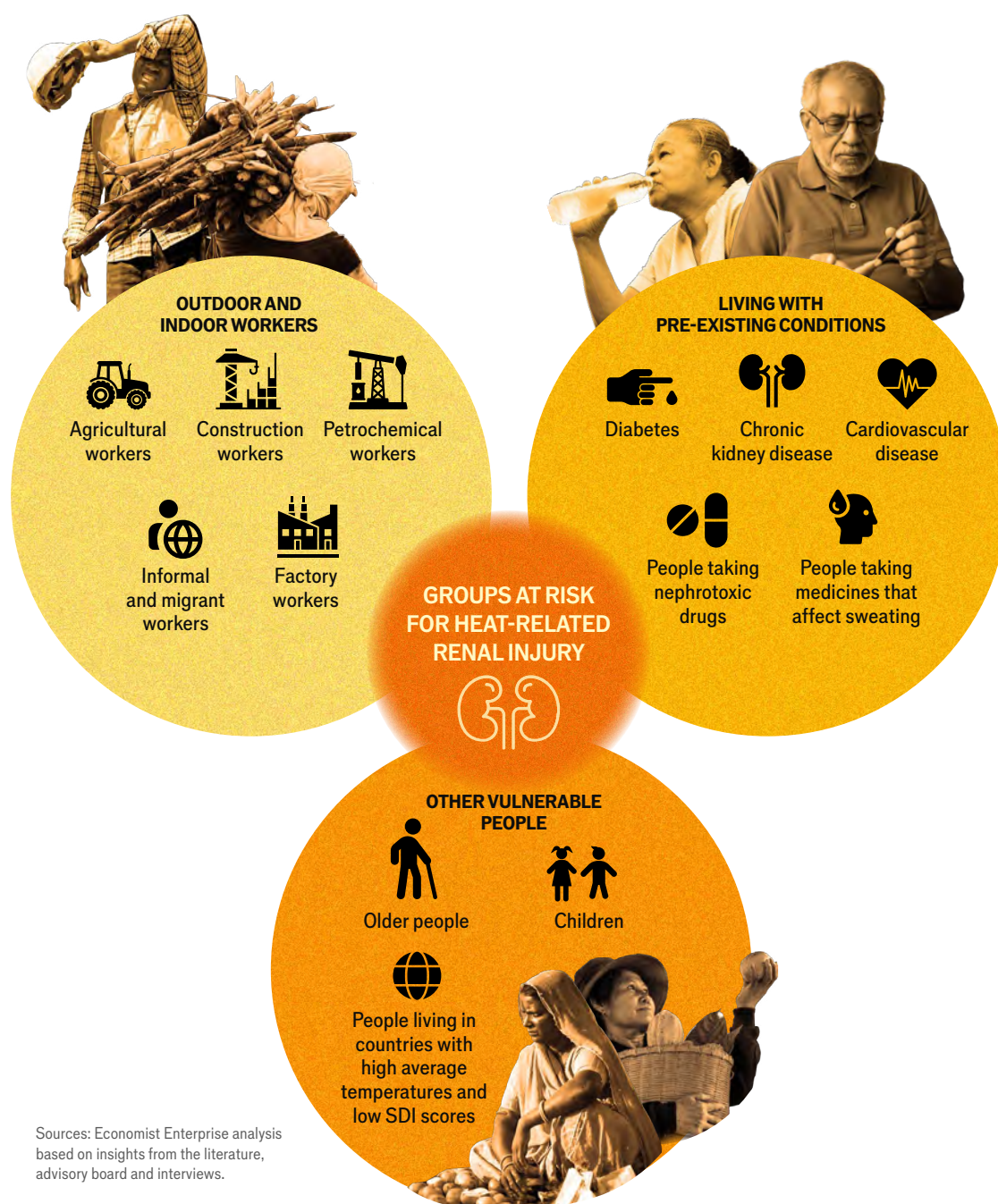
The greatest burden of heat-related kidney injury will be on vulnerable people and those living with pre-existing diseases, such as diabetes, kidney disease and cardiovascular disease.

Older and young people

Ageing reduces the body's ability to regulate heat, as sweating, blood flow to the skin and cardiac output all decline; a recent modelling study found that those aged 65 and older account for most heatwave-related increases in emergency visits and deaths amid climate change.⁴⁸

In the bulk of the research on hospital admissions, while these rose across much of the population, older people often showed an elevated kidney risk. An analysis of nearly a million AKI hospitalisations recorded in the UK Renal Registry, for example, found that for every increase of 1°C above a baseline of 25°C, the odds of an AKI incident seeking admission rose by 3.8%. The odds of admission were twice as high for those over 85 years old compared with those aged 45-64.⁴⁹ Meanwhile, a Chinese study of older people found that the more that participants experienced higher exposure to medium and extreme heatwaves over the course of five years, the more likely they were to see a rapid decline in kidney function.⁵⁰ Similarly, an analysis of 2.7m hospital admissions in Brazil for kidney diseases from 2000 to 2015 found that older people were among the highest risk groups, with those over 80 seeing their risk increase by 1% for each 1°C rise in daily mean temperature.⁵¹

Figure 2: At-risk groups for heat-related kidney injury



Some studies, though, also found heightened risk was not restricted to older people. In the Brazilian one, children under age five experienced a 3.5% increase in hospital admissions for every 1°C increase in temperature. This may reflect the greater difficulty young bodies have in dealing with heat.⁵² Meanwhile, a major study in China spanning 261 cities also showed a greater association between temperature increases and admissions for CKD

among those aged 18-60 than among older adults. That said, the differences were minor—an increased odds ratio of around 1%—and not statistically significant in sub-tropical and warm temperate zones.⁵³ Here the authors posit that younger adults may simply spend more time outside on hot days; a reminder of the importance of both risk and behaviour in understanding heat's impact on kidneys.

3.8%



An analysis of nearly a million acute kidney injury hospitalisations recorded in the UK Renal Registry found that for every increase of 1°C above a baseline of 25°C, the odds of an AKI incident seeking admission rose by 3.8%.

People living with pre-existing conditions: CKD, cardiovascular disease and diabetes

As Agnes Soares da Silva, director of the Department of Environmental Health and Occupational Health Surveillance at Brazil's Ministry of Health, notes, "anything that makes it difficult to cope with an additional physiological burden will put someone at higher risk of [kidney disease]." This general maxim definitely applies to certain NCDs. In fact, Dr Moura-Neto believes that heat's impact on people living with these conditions may be its biggest effect on the overall CVD burden.

The most predictable, perhaps, is that heat tends to make the condition of those with CKD worse. A study of more than 4,000 people with the condition across 21 countries found that more heat exposure was associated with greater deterioration in kidney function. Specifically, within any given 120-day period, 30 days with a combined temperature and humidity heat index above 30°C was associated

with a 0.6% decline in eGFR.⁵⁴ South Korean research also found a drop in eGFR among those with CKD for each degree increase in temperature above 25°C.⁵⁵ As Dr Caplin warns, "if you've got pre-existing kidney disease, even with a 'normal' GFR and no proteinuria, you are still at much greater risk of AKI." Eranga Wijewickrama, a nephrologist and professor at the University of Colombo, adds that "we need to address and mitigate heat stress in any population with CKD."

Those with other diseases also have an elevated risk of kidney damage in periods of high heat. The two most notable are CVD—or its precursors such as hypertension—and diabetes. Each shares a bidirectional relationship with kidney disease. At a global level, high glucose levels and high blood pressure are estimated to be behind half of CKD DALYs (nearly 32% and 25% respectively).⁵⁶ Similarly, approximately 12% of global CVD deaths in 2023 were attributable to kidney dysfunction.⁵⁷

It is, therefore, no surprise that kidney problems during heatwaves tend to be more common in those with CVD and diabetes.^{58,59,60}

Currently, the data available on heat, NCDs and kidney damage are more indicative than comprehensive. Dr Wijewickrama explains that mild heat stress can happen amid raised temperatures that are not full heatwaves—a much more common occurrence. "We also need to understand whether these lower levels of exposure accelerate kidney disease progression among people with pre-existing risks such as diabetes, hypertension or kidney disease."



"We also need to understand whether these lower levels of [heat] exposure accelerate kidney disease progression among people with pre-existing risks such as diabetes, hypertension or kidney disease."

Dr Eranga Wijewickrama, professor in medicine and consultant nephrologist, University of Colombo, Sri Lanka



Intense physical activity in hot conditions also may place additional strain on the kidneys through the combined effects of rising core temperature, dehydration and muscle damage, including rhabdomyolysis.

People taking certain medicines or foods

Certain drugs can promote dehydration, interfere with sweating or heat dissipation, reduce kidney blood flow, or directly damage the kidneys, including diuretics, some antidepressants, anticholinergic medicines, beta-blockers and non-steroidal anti-inflammatory drugs (NSAIDs).⁶¹ NSAID use has been associated with AKI among adults with existing kidney disease, while the risk may also increase when NSAIDs are taken together with both a diuretic and an ACE (angiotensin-converting enzyme) inhibitor or angiotensin receptor blocker.^{62,63}

What people drink may also matter. Beverages sweetened with **high-fructose corn syrup** have been associated with increased AKI risk

during exercise in the heat, although evidence from occupational settings remains limited.⁶⁴

Alcohol may further increase heat-related risk by increasing urination and impairing heat perception.⁶⁵ **Contaminated drinking water** containing pesticides or heavy metals may present an additional kidney hazard for people working in hot environments, but further research is needed to understand how these exposures interact.⁶⁶

Intense physical activity in hot conditions also may place additional strain on the kidneys through the combined effects of rising core temperature, dehydration and muscle damage, including rhabdomyolysis.^{67,68} This will be discussed in more detail in the section below.

Women, men and socio-economic status

Women experience CKD more often than men, with a 2016 global meta-analysis finding a prevalence of 14.6% versus 12.8% respectively.⁶⁹ Beyond that, different academic publications do not even agree on which gender is more likely to proceed to late stage kidney disease, although most agree that men are more likely to die from it.^{70,71,72}

An important reason for this uncertainty is that too few studies look at sex-specific differences. Women's kidneys, though, have markedly different structures, functions and appropriate measures of health. For example, women see GFR decline more quickly with the onset of menopause. One size does not fit all here.⁷³

This lacuna is relevant to heat as well. Indeed, says Professor Jha, "women are grossly, many completely, overlooked because their exposure to heat is just not appreciated." Even women described as staying at home, he adds, may be "exposed to high amounts of heat stress". Those at home, for example, may be vulnerable to indoor heat stress, due to cooking and other labour "which generates additional heat in poorly ventilated environments", says Carlos M Orantes Navarro, a nephrologist and research scientist in El Salvador. Without systematic investigation, though, the extent to which this translates into kidney damage remains unclear.

In addition, whether women are particularly at risk is uncertain. Heat certainly can hurt their kidneys. Those working in agriculture in the same conditions associated with CKDu among men are also likely to see similar kinds of health problems.⁷⁴

Meanwhile, a review of studies of urban areas during heatwaves found that, on balance, males were more likely to develop AKI during such situations, but the difference was not great. There was no statistically significant difference for CKD.⁷⁵ In short, heat is a concern for both genders, but we lack information on its particular effects on women.

The interaction between **socio-economic status** and heat-related CKD, both in general and CKDu, also requires examination. As noted earlier, countries with lower SDI have experienced larger relative increases in heat-related CKD prevalence. These regions are also almost invariably in Earth's higher-temperature zones, leaving unclear how far income levels or heat contribute to the problem. As Professor Ebi notes, "there may be less health and environmental data collected on poor and marginalised populations, whether internationally or within countries."

Those in low-income areas, all things being equal, are also less likely than the general population to have access to information on how to reduce CKD risk. Meanwhile, the mix of low pay, back-breaking work and challenging physical conditions involved in labour associated with high CKD levels, such as sugar cane or rice paddy harvesting, mean that such employment is more likely to be selected by people with greater financial need and fewer options. Finally, those of low socio-economic status or in low SDI countries face greater challenges with healthcare access and cooling.^{76,77}

In all these ways, while such demographic factors may not be initiators of CKD, they form, in the words of Dr Orantes, "a backdrop of social, occupational and environmental determinants where poverty and all its repercussions are part of the social context in which these communities, and the patients, are located." They affect not only the level of CKD rates but also amplify the disease's effect.

Says Mr Martinez, "the impact of kidney damage doesn't just affect the workers [who develop it]. When this person passes away in these communities [the almost inevitable outcome in lower-income countries], the emotional and economic impact on families and communities is incredible. It even affects the government, since the government lacks the capacity to address these types of situations. There are many people in need of dialysis, and the government cannot meet that demand."

As such, social conditions pose fundamental challenges to understanding the growing burden of CKD. Moreover, adds Dr Orantes, solutions must occur within the same context. In that way, he concludes, "kidney health is a social construct."

This underlines the importance of learning more about the links between socio-economic status, heat, and kidney disease, especially when it comes to the next group we discuss.



"Women are grossly, many completely, overlooked because their exposure to heat is just not appreciated."

Vivekanand Jha, executive director,
The George Institute for Global Health,
India

Workers

Workers may face kidney damage from heat, depending on the conditions in which they work. Studies of workers in places as far apart as Central America and Saudi Arabia have linked occupational heat exposure with acute kidney injury and subclinical kidney disease, raising concerns that repeated exposure may contribute to CKD.⁷⁸



Deaths from CKDu in young male labourers near Chichigalpa, Nicaragua, have led to the community being colloquially called ‘La Isla de Viudas’ (the Island of Widows).

Meanwhile, in India, about 19% of informal workers in a survey reported symptoms consistent with AKI. In other questions on negative health impacts from heat, that study showed that outdoor workers were most affected, but some indoor ones were as well.⁷⁹ Other research has found declines in GFR, a proxy measure of how well the kidneys filter blood, among workers exposed to heat.⁸⁰ The US Centers for Disease Control and Prevention and the National Institute for Occupational Safety and Health (NIOSH) have also highlighted kidney injury as a risk of occupational heat stress.⁸¹

Workers are a special group of study, as they were the sentinel population that has triggered discussions on how heat affects kidney health. As noted, most CKD arises from the damage that high blood sugar, hypertension, excess body mass or a combination that these cause to the kidneys. In recent decades, though, it has become apparent that workers, often young people, are at risk of kidney injury, including outdoor, indoor and informal workers. As Professor Ebi states, “epidemics of chronic kidney disease of unknown origin (CKDu) exist in Mesoamerica, Sri Lanka and some parts of India.”

Researchers are still trying to understand this disease better, but its impact has been great enough that it is mentioned in the WHO’s May 2025 resolution,⁸² and the draft AKI KDIGO guidelines now mention the effects of heat in a section called “Environmental and tropical AKI”.⁸³

Its burden is real and painful. Deaths in young male labourers near Chichigalpa, Nicaragua, have led to the community being colloquially called ‘La Isla de Viudas’ (the Island of Widows).⁸⁴ In the past decade, 46% of all male deaths in Chichigalpa were due to CKDu.⁸⁵

So far, even a standard name is still lacking. In the Pan American Health Organization region, what was initially called Mesoamerican Nephropathy (MeN) is now referred to as CKD of non-traditional origin (CKDnt). In Asia, it is more commonly called CKD of unknown aetiology (CKDu). The names reflect that the disease remains, to some extent, a diagnosis of exclusion, where we know more about which causes to rule out than about the single or mix of factors behind the problem. Like a unifying name, no agreement exists around robust definitions of the existing terms.⁸⁶

We do know that higher levels of CKDu (used as the general term from here on) tend to be focused within specific communities or regions. An ongoing global research collaboration, called the disadvantaged populations eGFR epidemiology (DEGREE) Study, is mapping these, and has so far analysed surveys of 60,964 people in 14 nations. Rather than relying on the number of diagnoses, the analysis looked at the percentage of the population without diabetes or hypertension who have an eGFR below the normal threshold (60mL/min/1.73 m²). It identified pockets where more than 5% of rural men showed this deficiency in Nicaragua, Sri Lanka and India, and more than 2% in parts of Guatemala. (In some areas, notably Uddanam, India, and parts of Northwest Nicaragua, the DEGREE Study found that the prevalence of CKDu reaches 14% among rural men). Among rural women, some groups also showed prevalence above 2% in the same countries, as well as in Ecuador, Tanzania and Kenya, although for females, fewer communities had a prevalence above 5%.⁸⁷

The DEGREE Study uses the eGFR data available. Signs of CKDu are also evident in other communities. In El Salvador, for example, research has found that CKDu is the most common form of CKD.⁸⁸ Moreover, in Costa Rica's Guanacaste province, a significant increase in age-standardised CKD mortality between 1970 and 2012 seems correlated with the expansion of agricultural activity there.⁸⁹ Perceptions of CKDu may also reflect what is being measured. In Nepal, a single-centre study found much higher than usual usage of dialysis among those who had worked outdoors in Qatar on construction, typically in difficult conditions.⁹⁰ Conversely, a comparison of average rates of low eGFR figures among such migrant workers and the population in general showed little difference.⁹¹

Teasing out the impact of these concentrations of CKDu on national mortality figures is not straightforward, but in some places, such as already-mentioned El Salvador, the disease has become an undeniable public health issue. Dr Wijewickrama, a nephrologist in Sri Lanka, describes CKDu as "one of the key [health] problems" there. The potential of CKDu to exact a devastating social impact is also obvious in certain particularly hard-hit communities, as noted for Chichigalpa, at the heart of Nicaragua's sugar cane farming sector.⁹² The result can be a tragic fatalism.

Mr Martinez, an occupational health expert at the La Isla Network (Nicaragua), who grew up and worked in the fields there, recalls the common mantra: "We cut cane, we get sick, and we die."

Heat's role in the growth of the CKDu burden

STATEMENT NO 4

There is associative evidence in certain occupational settings and geographies, (eg, among workers in Central America and Asia) linking the impacts of heat stress on kidney injury and disease, described as CKD unknown aetiology/CKD of non-traditional cause.

Why CKDu has become a growing problem since the turn of the century has been hotly debated. For many years, says Professor Ebi, researchers were "surprisingly blind to temperature" as a possible cause. Evidence certainly exists from some geographies that other factors are possibly involved, such as exposure to agrochemicals and heavy metals, typically in occupational settings; other exposures proposed to contribute to the development of CKDu include uric acid, infections, water quality and genetic factors.^{93,94}

Typically, though, discussions of CKDu a decade ago finished with an acknowledgement of a lack of understanding about the source of the 'enigmatic' disease. In recent years, notes Professor Ebi, researchers have begun to consider how heat exposure, especially at work, fits into the CKDu picture. As one recent review put it, "Associations between [heat] exposure and kidney damage are strong, consistent, and specific, occur after acute and chronic exposure, display dose-effect and dose-response relationships, are plausible, and coherent."⁹⁵ Dr Orantes, adds, though, that "there's a consensus that heat is an important factor," but "no single risk factor is exclusive because none can explain the spectrum of people affected. In fact, heat stress and dehydration could be a synergistic factor contributing to kidney damage resulting from occupational and toxic exposure to pesticides; in other words, none of these factors are mutually exclusive."⁹⁶



Projects to lower extreme heat exposure and promote hydration in affected workplaces have been shown to reduce subsequent rates of kidney damage.

Comments among those at the scientific advisory council were deliberately more calibrated. “There is general consensus that heat exposure is a driver of kidney disease or kidney injury,” said Professor Jha. “Whether or not it is a key driver can be up for debate.” He added that heat’s contribution to both the development and progression of kidney disease is generally accepted, based largely on epidemiological evidence from Central America and South Asia. Moreover, projects to lower extreme heat exposure and promote hydration in affected workplaces have been shown to reduce subsequent rates of kidney damage.⁹⁷

Heat, however, while an important driver of CKDu, is unlikely to explain everything. Most experts we interviewed for this study stressed that it was likely a significant contributor to the disease but that other causes were also likely at play. Others, including Jason Glaser, founder and CEO of La Isla Network, which works on projects to reduce heat exposure among workers in Central America, and Ifeoma Ulasi, head of nephrology at the University of Nigeria Teaching Hospital, argued that it might also be an initial cause of the disease but only in very specific situations of very high heat exposure. Mr Glaser distinguished these settings from less extreme exposures. “In those environments, it is sufficient to be an initiator,” he said. “In other environments, it is likely a contributor, possibly an initiator, but I think it is really important that we disentangle that.” Even then, they added, other potential drivers were typically present.

This kind of disagreement is not unusual among researchers. Professor Ebi reports that in the area of asthma, there is a debate over the extent to which higher pollen levels driven by climate change exacerbate pre-existing or lead to new cases of asthma. Ultimately, though, any debate over whether heat can be an initiator of CKDu or a huge driver has

limited policy consequences: taking steps to reduce heat exposure will drive down the burden of CKDu in either case.

Who specifically is at risk of CKDu?

Research on the condition initially focused tightly on sugar-cane cutters. Indeed, by 2019, a literature review found that 11 of the 13 studies then available on the condition looked at this occupation.⁹⁸ These workers met the key risk criteria—long hours of physically taxing work in high temperatures. Mr Martinez notes that, in these circumstances, when preventative steps are not taken, “the risk of developing heat-related kidney disease is overwhelming.” Accordingly, as Mr Glaser puts it, sugar cane workers are “the sentinel population and a really key area.”

Studies of other outdoor labourers frequently exposed to elevated heat show that many are also at risk. As Mr Martinez puts it, the drivers behind CKDu incidence in Central America, which “we’ve observed frequently and tracked extensively, are heat exposure combined with heavy workloads and inadequate conditions in agriculture, construction and the industrial sector.” Similarly, Kithsiri Jayasekara—professor in medical laboratory science at Sri Lanka’s General Sir John Kotelawala Defence University—adds that, in his country, “a person working in the open land with high or extremely high working temperature is at high risk.” He continues that heat interacts with other factors in creating this danger.

In agriculture, some groups are at greater risk, but it depends on the type of work. In Sri Lanka, **rice paddy employees** have very elevated levels of the disease, but those on vegetable farms experienced much lower ones.⁹⁹ Dr Jayasekara explains that many vegetable farms in that country are established at higher elevations, which are typically



The drivers behind CKDu incidence in Central America, which “we’ve observed frequently and tracked extensively, are heat exposure combined with heavy workloads and inadequate conditions in agriculture, construction and the industrial sector.”

William Martinez, occupational health expert, La Isla Network, Nicaragua

cooler. Similarly, among sugar-cane agricultural workers in Latin America overall, the incidence is elevated. One Nicaraguan study found this, but it also showed that those working on small-scale farms were not affected by CKDu.¹⁰⁰ This is broadly consistent with the research experience of Dr Orantes in El Salvador. He explains that, during biopsies, sugar cane workers’ lesions “were much more severe than those who worked only in **corn or bean farming**.” Among the latter, he adds, agrochemicals might be a factor causing the disease. These results, as a whole, are consistent with a heat-dose effect driving CKDu levels.

Evidence of risk also exists for outdoor workers in several other industries. **Construction workers** in Saudi Arabia were found to have high rates of kidney injury after the summer season,¹⁰¹ and those in Nicaragua saw an elevated prevalence of CKDu.¹⁰²

Meanwhile, **brickmakers** in Nicaragua and El Salvador showed an elevated prevalence of the disease.¹⁰³ Many **salt pan workers** in both Thailand and southern India also had diminished eGFR, with at least 7% of the latter having a rate consistent with CKD.¹⁰⁴ Similarly, a retrospective study of a group of Chinese **petrochemical workers**, who largely operated outdoors, found that occupational heat exposure was associated with elevated risk of CKD.¹⁰⁵

Others who are frequently outside may face a higher risk, but it is hard to pin down. US **military veterans** have higher overall rates of CKD than the general population (odds ratio of 1.17), but the data do not cover the kind of CKD and level of heat exposure over their service careers.¹⁰⁶ On the other hand, a study in Sri Lanka that specifically focused on CKDu found no elevated risk in military subjects.¹⁰⁷

Athletic activity in heat is also known to put stress on kidneys, and Korey Stringer, a US professional football player, famously died from organ failure after a massive heat stroke.¹⁰⁸ Nevertheless, evidence is lacking that elevated heat generates AKIs leading to CKD in any form among athletes except, perhaps, AKI in endurance sports.¹⁰⁹

Nor are the risks limited to those who go out into the sun. The evidence for CKDu, or even AKIs, is less extensive for **indoor workers**, but worrying signs exist. A study of industrial workers in Karnataka, India, found CKDu prevalence among manufacturing workers about half that of those employed in sugar cane.¹¹⁰ Meanwhile, an analysis of US Occupational Safety and Health Administration data identified 608 confirmed, possible or probable heat-related AKI cases, including 139 among indoor workers. More than three-quarters of the indoor cases occurred during June, July and August, suggesting that indoor heat risk can be amplified by seasonal outdoor temperatures.¹¹¹

That said, half of the sample also had hypertension, which means that the heat may have been acting in conjunction with that underlying risk rather than demonstrating new cases of CKDu.¹¹² Finally, research at a Brazilian foundry found a statistical association between working at higher temperatures and lower eGFR at the end of the shift.¹¹³ Not all of these studies are conclusive, but they collectively point in the same direction: high heat levels in indoor work may also bring kidney dangers.

This broader framing was repeatedly emphasised by the scientific advisory council. Mr Glaser cautioned that the field had allowed the problem to become framed as “outdoor work versus all heat-exposed work”, even though indoor workers in high-temperature industries may also experience severe kidney injury. Dr Anand similarly called for both “the outdoor work sector” and “indoor exposure” to be recognised, noting that indoor heat remains comparatively under-researched. Dr Orantes adds, even “those at home may be vulnerable to indoor heat stress” due to indoor cooking and other labour that “generates additional heat in poorly ventilated environments”.

Looking beyond occupation, certain demographic factors are linked to CKDu. A preponderance, although not all, of those affected are young and male.¹¹⁴ This statistical connection is more likely an indirect function of economic structure rather than one of biology. In these communities, the people most employed in the occupations that pose the greatest risk are young men. Moreover, the well-documented tendency of young males aged 15-35 to be much more risk-accepting than other groups suggests that changing behaviour will be a bigger challenge for this demographic slice.¹¹⁵

SECTION 2

The policy response: The time is now

STATEMENTS NO 6 AND 7

Policymakers should act now to address heat-related kidney risk rather than awaiting more detailed information on how heat and kidneys interact.

Policy responses should be multisectoral, combining health-system awareness and early detection with workplace protections, community education, and leadership from clinicians, public-health actors and professional societies.

Clearly, gaps, some important, cloud our understanding of the links between heat stress and kidney health, especially AKI and CKD. The expert consensus, though, is that we know enough to be getting on with prevention initiatives to reduce heat's kidney burden. Dr Moura-Neto speaks for many when he says, "we already have enough evidence to act. Hydration, shade, rest schedules, heat alerts, worker protection policies, educational programmes and targeted screening—none of them should wait for perfect scientific certainty to be implemented." Dr Orantes agrees: "Scientific evidence will always provide us with provisional truths, but public health cannot be held hostage by doubt, because we'd be waiting forever."

The levers with the potential to reduce heat's effect on kidney health are many and varied. Accordingly, effective prevention cannot be the job of a single

sector. In some cases, the best approach will involve collaboration among actors from several parts of society; other initiatives will fall naturally to those in a single sector. Behind it all will be the common aim of preventing kidney damage and disease through addressing the increasingly widespread challenge of heat stress.

The following looks at ways that four groups of stakeholders can help: first, broad, cross-societal collaborations for joint heat responsiveness, then ones more focused around specific areas of expertise.

2.1 International actions and multi-sectoral domestic government initiatives

International responses

Except in limited circumstances, international organisations lack the authority of their own to drive government action. Instead, they can use their influence to affect agendas on specific topics. The WHO 2025 resolution on kidney health is a useful example.¹¹⁶ For Vicente Sánchez Polo, head of the nephrology department in Guatemala's Social Security Programme, the document represents "a really big opportunity" since it "establishes CKD as a priority in our ministries and countries". The resolution is not unique in that way. Dr Orantes recalls that, already in 2013, the San Salvador Declaration of the Council of Ministers of Health of Central America and the Dominican Republic (COMISCA), which labelled CKD a significant public health problem,¹¹⁷ focused attention on its spread and led to fruitful information sharing within the region.

International bodies can also publish distilled expertise to help countries shape policies. Of note here are the WHO's detailed recommendations for national heat health action plans, which help countries prepare for and respond, in a coordinated way, to episodes of high heat.

The suggestions include: agreement on a lead body; accurate and timely alert systems; a heat-related health information plan; reduction in indoor heat exposure; care for vulnerable population groups; preparedness of the health and social care system; long-term urban planning; and real-time surveillance and evaluation. The document also gives advice on best practice in implementation.¹¹⁸

Similarly, the WHO and the World Meteorological Organisation (WMO) have worked together to help governments with heatwave management plans, starting in 2016 with joint guidelines for the creation of national and sub-national heatwave warning systems.¹¹⁹ Afterward, the two international bodies jointly supported the creation of the Global Heat Health Information Network (GHHIN), a voluntary team of experts who seek to assist governments at

all levels to “minimise the societal consequences of heat impacts”.¹²⁰

Ownership: The importance of domestic action

Ultimately, local ownership of the problem will drive change. After all, the specifics of climate, the possible impact of it changing and the options for responding vary widely by geography.

The efforts of international bodies have undergirded the spread of national and local plans, along with systems to prepare for, and deal with, extended periods of unusually high heat. Most of this work falls into two broad categories: heat action plans and heatwave early warning systems. In any given location, the two may be independent or the warning system may be part of the broader plan.

A growing body of heat plans—national, sub-national or urban—already exists. In 2024, GHHIN's database contained 83, mostly for local areas, although 18 were national.¹²¹ At least four more have been added to its library of plans since, all local.¹²² At the national level, Latin America has the highest concentration, with nine among its 17 countries having a plan in place.

There is no room here to generalise about, or summarise, the contents of so many documents. In general, they usually reflect aspects of the WHO advice and elements range widely from, for example, greening the urban environment by large-scale tree planting; through providing cooling, fresh water; offering other facilities to the public during extreme heat; and healthcare coordination, among other steps.

One particular widespread problem with these plans is worth flagging. Their existence on paper does not mean that they have much impact; it is necessary to monitor their implementation. Dr Soares da Silva explains that policymakers have begun only “very recently to take note of heat as a public health problem”. Accordingly, big teething problems and implementation gaps are frequent. A GHHIN report lists some common ones as: reactive, short-term management approaches; lack of clear roles and responsibilities; data gaps, lack of information integration and no clear and common taxonomy in this field; limited and disconnected financial mechanisms; and inequitable impact on vulnerable populations.¹²³



“Scientific evidence will always provide us with provisional truths, but public health cannot be held hostage by doubt, because we’d be waiting forever.”

Carlos M Orantes Navarro, nephrologist and research scientist, NefroCenter El Salvador

South Africa provides a good example of the gap between aspiration and practice. In a survey in Western Cape Province, 78% of provincial and municipal stakeholders were unaware of the country's National Heat Health Action Guidelines. The remainder were uncertain about their roles in implementing the advice.¹²⁴

Meanwhile, misalignment between costs and benefits can impede uptake. Professor Ebi says that the total cost of implementing these plans is low compared with the damage that they can prevent. But problems can arise if one local government agency is responsible for the costs—in US cities, fire departments are typically responsible for a significant fraction of the costs of providing emergency services—while the benefits are spread widely across governments, individuals and companies. Funders may be reluctant to pay more than they benefit directly, while others get a free ride.

This is only one example of a broader issue. Climate requires a comprehensive approach, but governments tend to be fragmented into silos. Whether a health system is even involved in climate change planning depends greatly on local circumstances.¹²⁵

On the other hand, very good and innovative programmes do exist. In 2024, Rio de Janeiro established one with five classes of heat risk. It then created a committee, including public order, health and other municipal officials, to develop protocols for who should be doing what at different levels of heat.¹²⁶ Already, Dr Soares da Silva says, the city has built an impressive information system to guide

its response. It combines temperature and climate data from across the city with health surveillance, infrastructure data such as drinking water availability and social indicators. These include the distribution of some government benefits, which serves as a proxy for communities at greater risk from heat.

On June 30th 2026, Brazil's national government launched a National Excess Heat Factor Dashboard. Dr Soares da Silva explains that it is built in part on the lessons from urban ones like Rio's. The National Dashboard also offers the option to combine weather data and social indicators (GeoSES) to assess heat risk across the country. It warns local authorities up to five days before heat risk rises, giving them time to prepare and respond.¹²⁷

Heatwave early warning systems are less common than heat plans. They are also of mixed quality and impact. In eastern and southern Africa, for example, where such plans exist, they too often fail to trigger any action.¹²⁸ To improve matters, in April 2026 WMO launched the WISER ActionFirst in Africa Initiative, which aims, among other things, to strengthen links between national meteorological bodies and disaster risk management agencies.¹²⁹

The effort will be worth it. As with heat plans, early warning systems can provide substantial benefits. A *Lancet* study of one such system in Shenzhen, China, looked at hospital admissions for heat-related illnesses between 2017 and 2023. On the first day after a given warning was issued, these admissions were, on average, 10% lower than on the day before the warning began.¹³⁰



Heatwave early warning systems are less common than heat plans. They are also of mixed quality and impact. In eastern and southern Africa, for example, where such plans exist, they too often fail to trigger any action.

“Very, very few, perhaps none, of the heatwave early warning systems answer ‘what do I need to do about kidney patients specifically?’”

Kristie Ebi, professor, Center for Health and the Global Environment at the University of Washington, US



Where can kidney health fit in?

In these plans, direct mention of, or provision for, kidney health is rare at best. A literature review conducted for this study found that most heat plans did not even mention kidney risks, or at most simply noted their link to periods of elevated heat. Similarly, to Professor Ebi's knowledge, “very, very few, perhaps none, of the heatwave early warning systems answer ‘what do I need to do about kidney patients specifically?’” In fact, because these are general documents that often cover a range of government activities and heat risks, even NCDs in general may not be explicitly considered.

In some ways, this makes little difference. Professor Jha believes that, for any effective response to high heat levels, certain “general principles hold true. These are common sense interventions, for example improving occupational conditions or giving people sensible advice regarding hydration. These don't require people to be aware of kidney disease.” In other words, sensible behaviour during the heat will help reduce the chances of all NCD-related health damage.

On the other hand, a failure even to mention specific diseases misses the chance to share possibly life-saving information. Dr Soares da Silva agrees

that, for the most part, the plans “cannot be disease specific”. But, she adds, the mention of individual conditions within a plan sends an important message to those who might be affected that they should take specific steps to protect themselves. Professor Ebi agrees, stating “if you have underlying or diagnosed kidney disease, you're at much greater risk” in these situations, so a heat warning should communicate these elevated dangers more clearly to those most affected. These alerts are also a possible channel for alerting relevant individuals about how higher temperatures might affect their medication.

2.2 The role of public health authorities and health system workers

Ultimately, health systems and public health bodies should, where possible, prevent kidney disease. When prevention fails, they should treat the disease promptly and effectively. This is as true when heat or other factors are behind kidney problems. The task is huge and multifaceted, but it is important to highlight some widespread challenges that stand in the way of progress.

Awareness

STATEMENT NO 5

Awareness of heat as a risk factor for kidney disease must improve, as it remains poorly recognised.

The first is raising the notoriously low levels of public awareness of kidney disease and all its risk factors. A review of 32 academic studies found that, even among those with some kidney ailment, consistently under half were aware that they had a problem. The only exception occurred when survey participants were actually sitting in nephrology clinics.¹³¹ Wider, awareness of risk is also poor. Indeed, a nationally representative British study for Kidney Research UK found that around eight in ten of the public did not know where the kidneys are in their bodies or what they do. Worse still, 60% of those who had some kidney risk did not think this was the case.¹³²



“People in the public health and clinical communities may recognise diabetes as a risk factor for kidney diseases but not that heat exposure can amplify risk too. We need to raise awareness [among them].”

Shuchi Anand, associate dean for global health and professor of medicine, UC Davis Health, US

Public awareness of the heat risk to kidneys appears to be, at best, limited.¹³³ Our experts see this in their work. Dr Ulasi, based in Nigeria, believes that appreciation of any heat-related health risk “is a problem in communities like mine. People say that they’ve lived with it all their lives. We need to get them to understand [the risks].” The issue goes beyond developing countries. Dr Anand reports that outdoor agricultural labourers in California, with whom she works, are not aware when their chosen work clothes “are insulating and potentially amplify their risk of heat exposure and indirectly, of kidney injury.” Nor will individuals likely learn of these risks from contact with the health system. Professor Ebi believes: “Most physicians don’t think about heat as a topic they need to discuss with their patients.”

But, if health systems are to improve public awareness, they first have to take the old advice: “Physician, heal thyself.” Heat’s danger to kidneys is under-recognised in the medical and public health communities,¹³⁴ and certainly not a priority. Indeed, Professor Jha reports that “in India, even the primary healthcare doctors don’t recognise the symptoms of heat stress. They simply dismiss them as exhaustion.” When public health professionals think about what needs to change in their own practices in Brazil, meanwhile, Dr Soares da Silva says that the link between heat and kidney disease “hardly comes up”. Meanwhile, Dr Anand, in California, says that “people in the public health and

clinical communities may recognise diabetes as a risk factor for kidney diseases but not that heat exposure can amplify risk too. We need to raise awareness [among them].”

Clinical guidelines

One way to do so is inclusion of heat risk in clinical guidelines that cover kidney diseases. Dr Soares da Silva advises this step for practical reasons: guidelines “help increase awareness among health professionals, who are not really interested in carbon footprints but in their patients.” Suitable guidelines would alert them to check, for example, if a patient with a given set of symptoms lives in a place without cooling, she explains.

For the most part, though, guidelines that link heat and kidney disease are few and far between. However, change could be coming. KDIGO’s current guidance documents for CKD and AKI do not refer to heat. Nevertheless, as noted earlier, the organisation’s draft 2026 AKI guidelines recommend that: “For children and adults presenting with AKD or AKI following prolonged exposure to high temperatures, consider heat injury as a cause of AKI.”¹³⁵

The spread of such advice to domestic guidelines for kidney health is likely to increase the ability of health systems to deal with kidney damage resulting from heat.

Health workforce

Among the increased challenges facing health systems as temperatures rise is finding the needed human resources.

Already, many countries suffer from a lack of expert kidney health professionals. *The Global Kidney Atlas* is based on surveys of nephrology organisations, patient groups and policymakers.¹³⁶ In its 2023 edition, respondents from most countries reported a shortage of nephrologists, transplant surgeons and dialysis nurses. It is perhaps predictable that the problem is most common in developing countries. Indeed, the ratio of nephrologists per head in high-income countries compared with those in lower-middle-income ones is 14:1. Nevertheless, better financed health systems sometimes share this deficiency. The accompanying map shows whether local respondents report a shortage. Much of Africa and parts of Latin America are affected, but so are certain Western European states, including Germany, Italy and Sweden.

Even where there are enough nephrologists, primary care—typically the first point of contact with the healthcare system—will inevitably have a major

role in kidney care. Without enough nephrology specialists, general practitioners (GPs) and their staff will be even more important to kidney care.

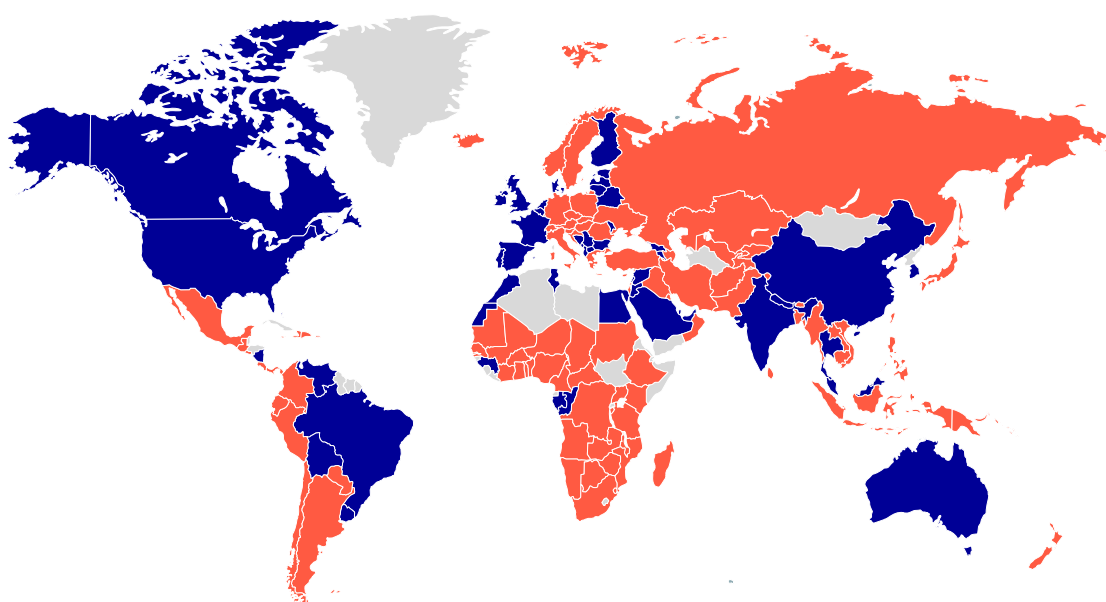
Primary care providers, though, often simply lack what they need for the task. One study analysed 20 surveys of GPs about barriers to kidney disease diagnosis and management. The most frequently named problem, common in over half of the surveys, was simply a lack of time. Poor guidelines were another frequent difficulty. This is especially worrying because in 40% of the surveys a large number of participants expressed low confidence in their own knowledge about this field.¹³⁷

Collectively, these kinds of difficulties can have big knock-on effects, even in relatively well-financed health systems. A recent Italian retrospective study of nearly 350,000 people aged over 40 found that just under a third of those who met the criteria for stage 3 CKD were actually diagnosed. The authors added that “substantial gaps in GP awareness and adherence to CKD management guidelines were identified, particularly in follow-up testing, referral practices, and diagnostic coding.”¹³⁸

Figure 3: Shortage of nephrologists, 2023

Insufficient nephrologists to meet kidney care demands (data from the global survey)

■ Yes ■ No ■ No data



Source: ISN-Global Kidney Health Atlas. <https://gkha.theisn.org/>

These workforce deficiencies on their own undermine kidney care in general. The lack of awareness of heat's potential role noted earlier means that heat-related kidney conditions are especially unlikely to be well served.

Other suggested workforce possibilities have included specialist nurses and community health workers. While a few successful pilot studies on the greater use of nurses have occurred, our research could find no studies showing the deployment of non-doctors at scale in CKD education, diagnosis and management.¹³⁹ Others in the community connected to healthcare can help in times of high heat. Professor Ebi explains that “pharmacists know every prescription drug everybody takes, but many reduce the body's ability to sweat and put users at higher risk.” Finding an ethical way for pharmacists to alert their customers to this risk in times of high heat would be very valuable.

Health systems and public health bodies are still learning how heat harms the kidneys. Many need clearer guidance and, in many countries, more staff to treat kidney disease of any kind. Too often, they are still laying the foundations before they can build on them.

The potential for targeted screening

CKD is sometimes called a silent disease, with few or even no symptoms until it reaches its late stages.¹⁴⁰ Until recently, however, screening for the condition was a matter of marked controversy. In order to reach a consensus on this question, in 2019 KDIGO held one of its Controversies Conferences. Participants' top three conclusions were: “Persons with hypertension, diabetes, or cardiovascular disease should be screened for CKD; ... CKD screening and treatment programs should also be implemented in other high-risk individuals and populations based on comorbidities, environmental exposures, or genetic risk factors; ... [and] The initiation, frequency, and cessation of CKD screening should be individualized based on kidney and cardiovascular risk.”¹⁴¹ Since then, in 2024, a study in the US found that screening the general population aged 55 years and over every five years was cost effective.¹⁴² A still more recent simulated modelling study even suggested that the starting age for cost-effective screening may be 45,

including in some developing countries. However, this research was based on simulations rather than information derived from pilot projects.¹⁴³

Emerging evidence also suggests that targeted screening may help identify early kidney dysfunction among workers exposed to high heat and heavy physical workloads. Repeat creatinine and eGFR testing during periods of sustained exposure appears promising; symptom-based tools and simple point-of-care markers may also help identify those at greater risk.^{144,145,146} However, the evidence remains limited, particularly on the best screening protocols, their longer-term benefits and their relevance beyond the occupational settings studied. Moreover, the lack of laboratory facilities needed for accurate testing makes point of care tools, especially in lower- and middle-income countries, problematic to deploy.¹⁴⁷ Of particular relevance to this study, Mr Glaser points out that high levels of heat make the leading point-of-care serum creatinine tests inaccurate.

As with any screening programme, or even guidelines on opportunistic screening, health systems have to weigh costs against likely benefits. The outcome of this calculation will differ by country and by which groups are considered for such an intervention. Even if not universally appropriate, in any given jurisdiction targeted CKD and AKI screening for specific groups may be worth the cost. Every health system should check where this might be the case for them.

2.3 The role of those shaping the workplace: Health and safety regulators, companies, workers and NGOs

Harnessing government regulation

Prevention, Dr Orantes notes, must “go beyond identifying sick individuals”. Kidney-related “interventions focused solely on the health sector will have limitations and won't be effective over time.”

In this task, he continues, government officials have important roles, notably those from the ministries of labour, the environment and social security. For CKD, though, especially the kinds closely tied to occupational activity, prevention

requires a still wider range of actors. Companies, NGOs, communities and individuals have a “shared responsibility”, Dr Orantes concludes.

Mr Martinez agrees about the need for such breadth, but also argues that, among those involved, “the government should bear the primary responsibility.” Its duty is to create good regulation in this field, “in order to ensure that all companies can protect their workers”. If well structured, these rules can also benefit businesses. Good companies will know what to do, and others will be compelled to take heat-related prevention seriously, creating a level playing field.

Government regulations and guidelines that specifically cover heat in the work environment exist in a few jurisdictions. Costa Rica's are probably the most advanced. For workers exposed to thermal stress, they mandate, among other measures, provision of suitable liquids, work-rest schedules with shaded rest areas, emergency procedures for responding to heat-related symptoms and kidney-specific occupational surveillance measures.¹⁴⁸ Brazil¹⁴⁹ and Nicaragua¹⁵⁰ also have workplace heat-related regulation, going back to 1977 and 2009 respectively, and the US NIOSH has guidelines on the matter too.¹⁵¹

A problem, though, is that these regulations and guidelines have limited impact on their own. Brazil's rules, Dr Soares da Silva explains, have “gaps in the legal framework which need to be dealt with” in order to align health best practice and regulation. In Nicaragua, meanwhile, the 2009 rules had already existed for eight years before La Isla began serious study of how to deal with pockets of CKD-driven devastation, such as on the Island of Widows. Finally, the US NIOSH guidelines are just that, not rules. Professor Ebi reports that only “five US states, out of 50, have regulations to protect outdoor workers. That's not impressive.”

What's more, even detailed regulations or guidelines, can be blunt instruments. In Mr Glaser's experience, “if you were to follow any of the so-called gold standard guidance, like that of NIOSH, on heat stress mitigation, nobody would work [outdoors] in the tropics. Nobody would work in the summer in Chicago, with even moderate workloads. And therefore, nobody tries to adhere to them.” But implementing a more nuanced understanding

of best practice, he adds, adapted to specific conditions “is not necessarily straightforward. Different jobs have different demands. Simple water, rest and shade won't always be sufficient.”

The need for a broader coalition

STATEMENT NO 8

Heat-risk policy should not rely on one-size-fits-all guidance; interventions need to be adapted to specific workplaces, indoor and outdoor settings, workloads and exposure patterns, then evaluated for implementation and impact.

Better heat-related prevention will require all of the stakeholders working together rather than simply adhering to regulations, however detailed or well-intentioned. As Dr Orantes puts it, “if public policies have not been sufficient, it is because there has been no interaction between businesses, citizens and the government sector. In the interest of seeking sustainable interventions, we should not continue carrying out disconnected activities.”

The particular coalition of actors needed in different situations will vary. Sometimes, government regulation and enforcement will still be able to do most of the heavy lifting. Dr Soares da Silva believes that “indoor settings are for the most part covered in Brazil because the rules are very clear. They require temperature control, ventilation, and cooling areas, etc.” Other situations, notably outside settings, are more complex.

In some of these, employers—perhaps advised by expert NGOs—should take the lead. For those working outdoors in sugar cane, Mr Martinez explains, the combination of rest, shade, hydration and recovery can be very effective. But design and implementation at individual workplaces are crucial. He adds that, in this environment, workers need to take an hourly rest, to do so in shade and to hydrate properly. “If you implement two of these, but fail to do the third one correctly, you won't achieve your results.” Managing these protocols are therefore best done on the spot by those in charge of the workplace, receiving advice when needed.

Conditions for other groups of workers also need attention, but the best approach is less clear. Several experts highlighted the challenges facing informal and gig workers, particularly those who work outdoors. In practice, these individuals are often beyond the reach of health regulation, let alone enforcement. Common sense suggests some potential ways to help. For example, Dr Soares da Silva mentions shaded public areas in which to rest and accessible water fountains for rehydration. They are valuable in every outdoor workplace, but particularly important where informal workers exercise control over how and when they take breaks.

While helpful ideas exist, so far, says Mr Martinez, the heat risk to informal workers “is a gap that must be addressed because, otherwise, the harm will continue. To put a stop to this problem, there has to be unity.”

Hearts and minds

Such unity, in turn, requires winning over the relevant stakeholders, whose interest is not guaranteed.

For workers, education about the risks can make a world of difference, especially in areas where heat’s impact on kidney health exacts a huge social and economic toll. As a result, says Mr Martinez, La

Isla’s new occupational programme will include an educational component that covers the heat risks to workers, the damage they can do and how to prevent them.

Success in reducing illness adds to the impact of teaching efforts. Around his organisation’s project sites, Mr Martinez reports, local residents have seen the drop in kidney disease. As a result, he continues, “they’ve come to understand that the only way to avoid getting sick is for workers to understand the risk they’re exposed to and take proactive steps to avoid getting sick.”

Meanwhile, other stakeholders might need different arguments. These include government officials—with invariably constrained budgets and available time—and cost-wary businesses. Arguments over responsibility for the drivers of CKD have limited effectiveness with these potential partners, says Dr Orantes. “Blame shouldn’t be the focus of the discussion. It has hindered our ability to find effective solutions.”

Instead, a growing research base covering the links of kidney disease and injury with heat, as well as the best ways to address them, will win over more organisations, he believes. Here, effective and ongoing research plays a central role.



Efforts to reduce the kidney health burden need to go beyond isolated interventions and instead “keep generating evidence so that these can be consolidated and incorporated into public policy.”

Carlos M Orantes Navarro, nephrologist and research scientist, NefroCenter El Salvador

Mr Martinez calls “numbers that are convincing” the most important tool “to convince both companies and the government”. As he points out, for example, a well-run rest, shade, hydration and recovery programme can not only reduce the disease burden among workers. It also leads to higher worker activity productivity, which gives companies a net saving on the costs of running the health intervention and reduces costs for the health service.¹⁵²

Outcome information from implemented initiatives can do much to make new ones even better. An ongoing learning loop, based on combining research and measurement with any new programme, is therefore crucial to long-term success. It can create coalitions for united efforts. As Dr Orantes explains, efforts to reduce the kidney health burden need to go beyond isolated interventions and instead “keep generating evidence so that these can be consolidated and incorporated into public policy.”

2.4 The role of the scientific and research community

There is enough evidence to begin addressing the risks that heat poses to kidney health. As Dr Soares da Silva explains, policymakers do not focus on the details of existing research. Instead, they react when the collective understanding of a problem creates societal awareness and “the political will to make changes”.

Nonetheless, some areas do need further research such as better understanding of the impact of heat on kidney health of women, informal workers and residents of substandard housing, especially in hot countries. Similarly, how heat interacts with kidney risks from contaminated water, toxic agents or alcohol consumption remains unclear.

This is not the place to devise a full research programme for the wide field of heat and kidney health. However, two research questions remain unresolved: the field’s very definition and better tools to support prevention of heat-related kidney damage.

Scientific and evidence gaps in the heat-kidney nexus revealed by our research

At various points, this study notes knowledge gaps, the filling of which could contribute greatly to

understanding of kidney disease and its interaction with heat exposure. The main ones include:

- Finding data on local CKD and AKI burdens, especially in developing countries.
- The quantitative relationship between heat exposure and various kidney-related diseases, as well as safe heat exposure thresholds.
- How heat’s effect on kidney health is ameliorated or exacerbated by socio-economic determinants, both internationally and within countries.
- How the impact of heat on kidney health does, or does not, differ by gender.
- The risks of high heat exposure for kidney health among those in other often understudied groups, such as people employed in industries that have not been studied, informal workers and those living in sub-standard accommodation.
- Best practice for integration of kidney health into heat action plans.
- The appropriate groups to cover with targeted screening for CKD in any given jurisdiction.
- Finding ways to deploy existing, low-cost kidney disease biomarker tests at the point of care.
- What an all-encompassing framework to cover heat’s overall impact on kidney health should look like.

Wrestling with the definition of heat-related kidney diseases: The need for an overarching framework

This field needs a wider lens: a more comprehensive understanding of the burden of heat-related kidney diseases. As noted in section 1, a **heat-kidney framework** is needed to move beyond diagnosis by exclusion and instead recognise heat exposure and the full spectrum of heat-related kidney injury.

The first step needs to be an expansion of the available data on the kidney disease burden overall, especially in developing countries. Registries help, although they take time to be able to paint a detailed picture of what is happening. For example, the African Renal Registry was established in 2015¹⁵³ and now seven countries participate. So far, though, only South Africa and Egypt have issued reports on their data, which are limited to patients with end-stage disease.¹⁵⁴



Current conceptual and analytical frameworks “don’t fully capture the broader spectrum of heat-related kidney injury, including recurring acute kidney injury, the acceleration of existing CKD and climate-associated kidney vulnerability.”

Guillermo Garcia-Garcia, a professor at the University of Guadalajara

Similarly, an Indian registry has not reported since 2012.¹⁵⁵ Nor do these registries have data on heat exposure before any kidney disease diagnosis.

The most substantial body of current research relevant to the link between heat and kidney disease is that looking at CKDu, which often includes consideration of the role of heat in the condition’s pathogenesis. The ongoing, global DEGREE Study

was mentioned earlier. Similarly, the Consortium for the Epidemic of Nephropathy in Central America and Mexico is a group of researchers working on understanding CKDu in that region, including what it calls the leading role of heat stroke in its development.¹⁵⁶ Meanwhile, individual studies too numerous to detail, and many mentioned in this report’s footnotes, have covered the links between CKDu and heat in various countries in Central America, India, Sri Lanka, Africa, Thailand and China.

These are certainly valuable in understanding the degree of the challenge. Indeed, Professor Ebi reports, “as more analyses [of heat-related health damage] are done, we’re finding out that more and more people are being harmed than we understood.”

The research so far, though, is far from sufficient for understanding the nexus of heat and AKI and CKD for two reasons. To begin with, while CKDu is associated with heat stress in many geographies, as our experts noted earlier, that is not its sole cause. Heat’s relative contribution to the disease burden, as well as those environmental and other risks still needs to be teased out for heat’s specific role to become clear.

Nor does all heat-related CKD fall under any definition of CKDu. Dr Moura-Neto sees conflation of CKDu and heat-related CKD as a “limitation”. He points out that “from a population perspective, heat may have an even greater impact by accelerating kidney function decline in people with diabetes, hypertension, obesity, aging and preexisting chronic kidney disease.” Mr Glaser agrees that dividing data into CKDu and CKD can obscure heat’s contribution to the burden of the latter.

In order to understand the link between high levels of heat overall and all forms of CKD, researchers need to devise a more all-encompassing framework. Dr Moura-Neto suggests that people should start looking at heat-induced disease as part of a spectrum. Guillermo Garcia-Garcia, a professor at the University of Guadalajara, adds that current conceptual and analytical frameworks “don’t fully capture the broader spectrum of heat-related kidney injury, including recurring acute kidney injury, the acceleration of existing CKD and climate-associated kidney vulnerability. Future frameworks need to evolve.”

The goal makes sense, but the idea has a long way to go. As with CKDu, nomenclature reveals disagreements among experts. Terms such as heat-stress¹⁵⁷ or, less often, heat-related nephropathy¹⁵⁸ have appeared in the last few years but, as Dr Wijewickrama and Dr Caplin argue, these might, because of the implicit emphasis they place on heat's role, obscure other causal factors. Dr Caplin recommends a different descriptor such as "heat-exacerbated". Nor is biology able to lend a hand. Professor Jha explains that biomarkers are still lacking to show "with any degree of certainty about the contribution of heat to the development of a kidney injury or kidney disease." Finally, basic biological questions remain unsolved, such as whether it is even possible to talk about a dose-response relationship between heat and kidney damage given differences in how people might be affected on an individual level.

Nevertheless, if the general population, medical community and policymakers are to see the wide range of ways in which excess heat contributes to CKD, let alone AKI or other kidney damage, researchers need to develop an overarching framework to classify and explain the phenomenon.

Detection and biomarkers

There is also a need for better use of tools or protocols to detect AKI or to prevent other heat-related kidney damage.

As discussed earlier in the section on screening, point of care testing remains a challenge, especially in lower- and middle-income countries. Ultimately, though, newer tests, which often require advanced laboratory facilities, are unlikely to be the answer. Professor Jha explains that "we don't need fancy biomarkers [to identify risk]. We simply need to implement the tests that we know help us to identify early kidney disease such as ones for albuminuria. Serum creatinine is also not bad: it's just that we don't measure it well enough."

The ongoing challenge is to find ways to gain information on known risk-related biomarkers that can be used for rapid prevention interventions. Any protocol may want to start with the simplest step: asking people how they feel. A Sri Lanka study found that self-reported heat stress symptoms might be used to help in screening for AKI.¹⁵⁹

These examples are far from an exhaustive research agenda, but they show that pressing questions range from the very broad to the highly detailed.

Conclusion and policy takeaways

We live in a warming world that will not simply bring higher average temperatures, but is also already seeing an increasing number of episodes of extreme heat. These outcomes can, in turn, increase the burden of kidney disease.

Already, evidence from heatwaves shows that groups such as older people, those living with CKD and those with NCDs that frequently interact with it, notably CVD and diabetes, are at risk of AKI episodes and new or more serious CVD.

Meanwhile, a new epidemic of kidney disease is closely associated with occupations where one common factor is exposure to high levels of heat while working and poor cooling, hydration and rest practices. Higher temperatures will only exacerbate that risk.

Poverty, where it limits access to cooling, healthcare or safe working conditions, can further amplify the effects of heat on kidney disease.

Facing this pressing public health challenge, policymakers can take important steps now to lessen the heat burden. These fall into several categories:

1. **Need for all-of-government initiatives that turn heat plans into action.** Heat plans can help cities redesign public spaces to reduce heat exposure and protect residents. They also give public officials a clear framework for responding to heatwaves. Jurisdictions without heat plans should develop ones that suit their institutions and needs. Too many existing plans remain lists of ambitions rather than practical measures. Governments must back them with funding, clear responsibilities and coordination across agencies. Heatwave warning systems also save lives by helping people to prepare for dangerous conditions. Including advice for people at higher risk of kidney disease and other heat-related illnesses would make these systems more effective. International organisations can support these efforts by raising awareness of kidney disease and sharing good practice on heat plans and warning systems.



2. **Health systems should strengthen kidney care and raise awareness of heat-related kidney risks across the health workforce.**

Health systems need enough kidney specialists, but they also need to equip primary care doctors, nurses, pharmacists and other frontline health workers to recognise, detect, prevent and manage heat-related kidney injury. Clear clinical guidance, training and public health messaging can help healthcare professionals identify those most at risk and intervene earlier. Without greater investment in kidney care, stronger clinical capacity and wider awareness of how heat affects kidney health, health systems will struggle to cope as heatwaves become more frequent and severe. Finally, health systems should consider which targeted screening of at-risk individuals is appropriate for their jurisdiction and its specific disease burden.

3. **Governments, employers, employees and NGOs should work together to protect workers from heat.** Governments should introduce and enforce workplace heat standards where these do not already exist. The rules

should set minimum protections while allowing employers to adapt them to local conditions and different types of work. Employers, workers and NGOs should work together to develop practical measures that reduce heat exposure and protect kidney health. Done well, these measures can improve worker health, reduce lost productivity and benefit businesses as well.

4. **Scientists and researchers should focus on the evidence needed to protect kidney health in a hotter world.**

Researchers in academia, government, industry and NGOs should work together to close the most important knowledge gaps such as the quantitative relationship between heat exposure and various kidney-related diseases, as well as safe heat exposure thresholds, the impact of heat on women's kidney health and the need for an overarching heat-kidney framework. Researchers should also assess which policies and interventions work and why, so governments, employers and health systems can learn from experience and improve their response over time. Better evidence will help turn awareness into more effective action.

References

- Economist Enterprise. Vision 2030: Climate adaptation for improved cardiovascular-renal-metabolic health outcomes [Internet]. London: The Economist Group; 2026 [cited 2026 Aug 12]. Available from: <https://insights.economistenterprise.com/health-society/climateadaptationandhealth/cardiovascular-renal-metabolic-outcomes>
- Emerton R, Nicolas J, Lombardi A, et al. Global heat stress intensification and its expanding footprint on the human population. *Nature Climate Change* [Internet]. June 22 2026;16(8):989–96. Available from: <https://www.nature.com/articles/s41558-026-02670-5>
- UNEP. Emissions Gap Report 2025: Off Target [Internet]. Nairobi. UNEP. 2025. Available from: <https://wedocs.unep.org/rest/api/core/bitstreams/4830e1a8-14c0-44a5-a066-cdd2ba5b3e10/content>
- World Health Organization. Heat and health [Internet]. Geneva: World Health Organization; July 13 2026 [cited July 14 2026]. Available from: <https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health>
- Xu J, Wang Q, Anikeeva O, et al. Effects of extreme heat on physiology, morbidity, and mortality under climate change: mechanisms and clinical implications. *BMJ* [Internet]. October 29 2025;391:e084675. Available from: <https://www.bmj.com/content/391/bmj-2025-084675>
- The Lancet. High temperature—Level 3 risk [Internet]. The Lancet. October 17 2020. Available from: <https://www.thelancet.com/pb-assets/Lancet/gbd/summaries/risks/high-temperature.pdf>
- The Lancet. Key findings of the 2025 Report of the Lancet Countdown on Health and Climate Change: Climate change action offers a lifeline [Internet]. Available from: <https://lancetcountdown.org/2025-report-visual-summary/>
- Emerton R, Julien N, Lombardi A, et al. Global heat stress intensification and its expanding footprint on the human population. *Nature Climate Change* [Internet]. June 22 2026;1–8. Available from: <https://www.nature.com/articles/s41558-026-02670-5>
- Lizana J, Miranda ND, Sparrow SN, et al. Global gridded dataset of heating and cooling degree days under climate change scenarios. *Nature Sustainability* [Internet]. January 26 2026;9(3):470–80. Available from: https://www.researchgate.net/publication/400086337_Global_gridded_dataset_of_heating_and_cooling_degree_days_under_climate_change_scenarios
- Emerton R, Julien N, Lombardi A, et al. Global heat stress intensification and its expanding footprint on the human population. *Nature Climate Change* [Internet]. June 22 2026;1–8. Available from: <https://www.nature.com/articles/s41558-026-02670-5>
- National Kidney Foundation. Acute Kidney Injury (AKI) [Internet]. Updated February 2024. Available from: <https://www.kidney.org/kidney-topics/acute-kidney-injury-aki>
- KDIGO 2026 Clinical Practice Guideline for Acute Kidney Injury (AKI) and Acute Kidney Disease (AKD). Public Review Draft [Internet]. March 2026. Available from: <https://kdigo.org/wp-content/uploads/2026/03/KDIGO-2026-AKI-AKD-Guideline-Public-Review-Draft-March-2026.pdf>
- Chawla LS, Kimmel PL. Acute kidney injury and chronic kidney disease: an integrated clinical syndrome. *Kidney International* [Internet]. September 2012;82(5):516–24. Available from: [https://www.kidney-international.org/article/S0085-2538\(15\)55599-3/fulltext](https://www.kidney-international.org/article/S0085-2538(15)55599-3/fulltext)
- The Lancet. The next steps for chronic kidney disease. *The Lancet* [Internet]. June 2026;407(10546):2345. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(26\)01183-9/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(26)01183-9/fulltext)
- Lees JS, Zhang L, Anandh U, et al. Advances in the diagnosis and detection of chronic kidney disease. *The Lancet* [Internet]. June 2026;407(10546):2414–28. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(26\)00702-6/abstract](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(26)00702-6/abstract)
- National Kidney Foundation. Chronic Kidney Disease (CKD) [Internet]. Updated September 2023. Available from: <https://www.kidney.org/kidney-topics/chronic-kidney-disease-ckd>
- UK Kidney Association. CKD staging [Internet]. Available from: <https://www.ukkidney.org/health-professionals/information-resources/uk-eckd-guide/ckd-staging>
- Heat stress is the net heat load experienced by an individual, accounting for environmental and personal factors. It reflects the combined effects of air temperature, humidity, wind and solar radiation, as well as how the human body responds to those conditions. In this study, heat stress is measured using the Universal Thermal Climate Index and expressed as a “feels-like” temperature.
- WHO. Reducing the burden of noncommunicable diseases through promotion of kidney health and strengthening prevention and control of kidney disease [Internet]. May 27 2025. Available from: https://apps.who.int/gb/ebwha/pdf_files/WHA78/A78_R6-en.pdf
- World Health Organization. Reducing the burden of noncommunicable diseases through promotion of kidney health and strengthening prevention and control of kidney disease. Geneva. World Health Organization. February 3 2025. Document No.: EB156/CONF/6. Available from: https://apps.who.int/gb/ebwha/pdf_files/EB156/B156.CONF6-en.pdf
- Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxE52knnUQ_IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxE52knnUQ_IQnGM8y2X8s6Ltl)
- Kadowaki T, Maegawa H, Watada H, et al. Interconnection between cardiovascular, renal and metabolic disorders: A narrative review with a focus on Japan. Vol. 24, *Diabetes, obesity & metabolism* [Internet]; 2022. p. 2283–96. Available from: <https://pubmed.ncbi.nlm.nih.gov/35929483/>
- Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxE52knnUQ_IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxE52knnUQ_IQnGM8y2X8s6Ltl)
- Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. *Nephron Clin Pract* [Internet]. 2012; 120(4):c179–84. Available from: <https://doi.org/10.1159/000339789>
- NICE. How should I diagnose acute kidney injury? [Internet] July 2023 revision. Available from: <https://cks.nice.org.uk/topics/acute-kidney-injury/diagnosis/diagnosis/>
- Phu Tran NT, Phannajith J, Harnpramukul P, et al. WCN26-2720 GLOBAL BURDEN OF ACUTE KIDNEY INJURY: EPIDEMIOLOGY, MORTALITY, AND DISABILITY-ADJUSTED LIFE YEARS. *Kidney International Reports* [Internet]. April 2026;11(4):105662. Available from: https://www.researchgate.net/publication/403361094_WCN26-2720_GLOBAL_BURDEN_OF_ACUTE_KIDNEY_INJURY_EPIDEMIOLOGY_MORTALITY_AND_DISABILITY-ADJUSTED_LIFE_YEARS

27. Mark P, Stafford L, Grams M et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet*, 2025; 406:2461–2482. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext#supplementary-material](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext#supplementary-material)
28. Supplementary material. Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext#supplementary-material](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext#supplementary-material)
29. Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpZAHn4jP64Z6R4vsjBUVK_TyUa.mMvkincc8-1788163805-1.0.1.1-DsIXwCZ.6uxyTqTtEGe52knnUQ.IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpZAHn4jP64Z6R4vsjBUVK_TyUa.mMvkincc8-1788163805-1.0.1.1-DsIXwCZ.6uxyTqTtEGe52knnUQ.IQnGM8y2X8s6Ltl)
30. Supplementary material 1. Burkart K, Brauer M, Aravkin A, et al. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *The Lancet* [Internet]. 2021; 398:685–697. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)01700-1/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01700-1/fulltext)
31. Supplementary material 1. Burkart K, Brauer M, Aravkin A, et al. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *The Lancet* [Internet]. 2021; 398:685–697. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)01700-1/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01700-1/fulltext)
32. Papersflow. Global Burden of Disease Estimation Methods Research Guide [Internet]. Accessed August 25 2026. Available from: <https://papersflow.ai/research/topics/healthcare-systems-and-public-health/global-burden-of-disease-estimation-methods#key-research-challenges>
33. Zhao ZY, Li JJ, Ouyang HQ, et al. Enhancing regional disease burden estimates: insights from the comparison of Global Burden of Disease and China's notifiable infectious diseases data with policy implications (2010–2020). *Infectious Diseases of Poverty* [Internet]. August 6 2025;14(1). Available from: <https://doi.org/10.1186/s40249-025-01351-3>
34. He L, Xue B, Wang B, et al. Impact of high, low, and non-optimum temperatures on chronic kidney disease in a changing climate, 1990–2019: A global analysis. *Environmental Research* [Internet]. 2022;212(Pt A):113172. Available from: [doi:10.1016/j.envres.2022.113172](https://doi.org/10.1016/j.envres.2022.113172)
35. Burkart K, Brauer M, Aravkin A, et al. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *The Lancet* [Internet]. 2021; 398:685–697. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)01700-1/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01700-1/fulltext)
36. Ebi K, Capon A, Berry P, et al. Hot weather and heat extremes: health risks. *The Lancet* [Internet]. 2021; 398, 698–708. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(21\)01208-3/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01208-3/fulltext)
37. Chapman CL, Johnson BD, Parker MD, et al. Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. *Temperature* [Internet]. October 13 2020;8(2):108–59. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8098077/>
38. Elinder CG. Heat-induced kidney disease: Understanding the impact. Vol. 297, *Journal of internal medicine* [Internet]. 2025. p. 101–12. Available from: <https://pubmed.ncbi.nlm.nih.gov/39607397/>
39. Sasai F, Roncal-Jimenez C, Rogers K, et al. Climate change and nephrology. Vol. 38, *Nephrology, dialysis, transplantation* [Internet]. 2023. p. 41–8. Available from: <https://pubmed.ncbi.nlm.nih.gov/34473287/>
40. Chapman CL, Johnson BD, Parker MD, et al. Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. *Temperature* [Internet]. October 13 2020;8(2):108–59. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8098077/>
41. Claude-Del Granado R, Lumlertgul N. Climate change and AKI: heat, hazards and health-system readiness. *Nat Rev Nephrol* [Internet]. March 2026;22(3):171–173. Available from: <https://www.nature.com/articles/s41581-026-01048-2>
42. Tseng MF, Chou CL, Chung CH, et al. Risk of chronic kidney disease in patients with heat injury: A nationwide longitudinal cohort study in Taiwan. *PLoS One* [Internet]. July 2 2020;15(7):e0235607. Erratum in: *PLoS One*. September 2 2020;15(9):e0238826. Available from: <https://pubmed.ncbi.nlm.nih.gov/articles/PMC7332078/>
43. Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *Am J Physiol Renal Physiol* [Internet]. February 1 2024;326(3):F499–F510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
44. Chapman CL, Johnson BD, Parker MD, et al. Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. *Temperature* [Internet]. October 13 2020;8(2):108–59. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8098077/>
45. Chawla LS, Kimmel PL. Acute kidney injury and chronic kidney disease: an integrated clinical syndrome. *Kidney International* [Internet]. September 2012;82(5):516–24. Available from: [https://www.kidney-international.org/article/S0085-2538\(15\)55599-3/fulltext](https://www.kidney-international.org/article/S0085-2538(15)55599-3/fulltext)
46. Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
47. World Health Organization. #KeepCool in the heat [Internet]. 2026. Available from: <https://www.who.int/europe/news-room/fact-sheets/item/keepcool-in-the-heat>
48. Kong Q, Vecellio DJ, Huber M, et al. Exceeding human heat tolerance in a warming, ageing world: a global projection modelling study. *The Lancet Planetary Health* [Internet]. 2027. p. 101494. Available from: <https://pubmed.ncbi.nlm.nih.gov/42607702/>
49. Bodapati N, Hajat S, Steenkamp R, et al. Heat-related acute kidney injury risk in England: a nationwide case-crossover analysis of 947 342 AKI alerts. *Clin Kidney J* [Internet]. March 20 2026;19(4):sfag100. Available from: <https://pubmed.ncbi.nlm.nih.gov/articles/PMC13078161/>
50. Zhang J, Wang B, Ye B, et al. Association between heatwave exposure and rapid kidney function decline: a longitudinal cohort study from CHARLS. *BMC Public Health* [Internet]. April 30 2025;25(1):1596. Available from: <https://pubmed.ncbi.nlm.nih.gov/articles/PMC12042415/>
51. Wen B, Xu R, Wu Y, et al. Association between ambient temperature and hospitalization for renal diseases in Brazil during 2000–2015: A nationwide case-crossover study. *The Lancet Regional Health - Americas* [Internet]. February 2022;6:100101. Available from: <https://doi.org/10.1016/j.lana.2021.100101>
52. UNICEF. Heat Waves and How They Impact Children [Internet]. Accessed July 22 2026. Available from: <https://www.unicef.org/stories/heat-waves-impact-children>
53. Wang FL, Wang WZ, Zhang FF, et al. Heat exposure and hospitalizations for chronic kidney disease in China: a nationwide time series study in 261 major Chinese cities. *Military Medical Research* [Internet]. September 5 2023;10(1). Available from: <https://pubmed.ncbi.nlm.nih.gov/42607702/>
54. Zhang Z, Heerspink HJL, Chertow GM, et al. Ambient heat exposure and kidney function in patients with chronic kidney disease: a post-hoc analysis of the DAPA-CKD trial. *The Lancet Planetary Health* [Internet]. April 2024;8(4):e225–33. Available from: [https://www.thelancet.com/journals/lanph/article/PIIS2542-5196\(24\)00026-3/fulltext](https://www.thelancet.com/journals/lanph/article/PIIS2542-5196(24)00026-3/fulltext)
55. Park MY, Ahn J, Bae S, et al. Effects of cold and hot temperatures on the renal function of people with chronic disease. *Journal of Occupational Health* [Internet]. January 1 2024;66(1). Available from: <https://academic.oup.com/joh/article/66/1/uaie037/7714547>

56. Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl)
57. Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl)
58. Mark PB, Stafford LK, Grams ME, et al. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. *The Lancet* [Internet]. November 2025;406(10518):2461–82. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01853-7/fulltext?_cf_chl_tk=gSZeJpzZAHn4jP64Z6R4vsjjBUVK_TyUa.mMvkinkc8-1788163805-1.0.1.1-DslXiwCZ_6uxyTqxTEGe52knnUQ_IQnGM8y2X8s6Ltl)
59. Luo H, Yu T, Gao Y, et al. Heat-related mortality burden of type 1 diabetes, type 2 diabetes, and diabetes complications in mainland China amid global warming: a nationwide, case-crossover study. *The Lancet Planetary Health* [Internet]. December 2025;9(12):101384. Available from: [https://www.thelancet.com/journals/lanph/article/PIIS2542-5196\(25\)00262-1/fulltext](https://www.thelancet.com/journals/lanph/article/PIIS2542-5196(25)00262-1/fulltext)
60. Bodapati N, Hajat S, Steenkamp R, et al. Heat-related acute kidney injury risk in England: a nationwide case-crossover analysis of 947 342 AKI alerts. *Clin Kidney J* [Internet]. March 20 2026;19(4):sfag100. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC13078161/>
61. Centers for Disease Control and Prevention. Heat and medications: Guidance for clinicians [Internet]. September 18 2025. Available from: <https://www.cdc.gov/heat-health/hcp/clinical-guidance/heat-and-medications-guidance-for-clinicians.html>
62. Lapi F, Azoulay L, Yin H, et al. Concurrent use of diuretics, angiotensin converting enzyme inhibitors, and angiotensin receptor blockers with non-steroidal anti-inflammatory drugs and risk of acute kidney injury: nested case-control study. *BMJ* [Internet]. January 8 2013;346:e8525–5. Available from: <https://www.bmj.com/content/346/bmj.e8525>
63. Teo SH, Tan NC, Choo JCJ, et al. Non-steroidal anti-inflammatory drugs in chronic kidney disease and risk of acute adverse kidney events according to route of administration. *International Urology and Nephrology*. September 5 2022;55(3):679–86.
64. Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
65. Centers for Disease Control and Prevention. Heat and medications: Guidance for clinicians [Internet]. September 18 2025. Available from: <https://www.cdc.gov/heat-health/hcp/clinical-guidance/heat-and-medications-guidance-for-clinicians.html>
66. Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
67. Chapman CL, Johnson BD, Vargas NT, et al. Both hyperthermia and dehydration during physical work in the heat contribute to the risk of acute kidney injury. *Journal of Applied Physiology* [Internet]. April 1 2020;128(4):715–28. Available from: <https://doi.org/10.1152/jappphysiol.00787.2019>
68. Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
69. Hill NR, Fatoba ST, Oke JL, et al. Global Prevalence of Chronic Kidney Disease – A Systematic Review and Meta-Analysis. Remuzzi G, editor. *PLOS ONE* [Internet]. July 6 2016;11(7). Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4934905/>
70. Kattah AG, Garovic VD. Understanding sex differences in progression and prognosis of chronic kidney disease. *Ann Transl Med* [Internet]. July 2020;8(14):897. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC7396766/>
71. Harvey BJ, Alvarez de la Rosa D. Sex Differences in Kidney Health and Disease. *Nephron* [Internet]. 2024 Autumn;1–27. Available from: <https://pubmed.ncbi.nlm.nih.gov/39406203/>
72. Lees J, Stevens K, Kotwal S, et al. Advances in understanding the impact of sex on kidney health and disease. *The Lancet* [Internet]. 2026; 407:2429–2443. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(26\)00654-9/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(26)00654-9/fulltext)
73. Lees J, Stevens K, Kotwal S, et al. Advances in understanding the impact of sex on kidney health and disease. *The Lancet* [Internet]. 2026; 407:2429–2443. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(26\)00654-9/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(26)00654-9/fulltext)
74. Butler-Dawson J, Jaramillo D, Krisher L, et al. A work and off-work evaluation of female workers' heat and particulate matter exposures and kidney health in Guatemala. *J Clim Chang Health* [Internet]. 2025 Mar-Apr;22:100408. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12448058/>
75. Seo SH, Go S, Jeong Y. Environmental Heat and Renal Health Across Cosmopolitan Populations: A Scoping Review Focused on Sex-Specific Vulnerability. *International Journal of Public Health* [Internet]. March 25 2026;71. Available from: <https://www.ssph-journal.org/journals/international-journal-of-public-health/articles/10.3389/ijph.2026.1609356/full>
76. WHO and IBRD. Tracking universal health coverage: 2025 global monitoring report [Internet]. 2025. Available from: <https://iris.who.int/server/api/core/bitstreams/04e720a0-bf22-4fb8-ad42-d6296bba739f/content>
77. Falchetta G, Mazzone A, Bhasin S, et al. A multidimensional assessment of systemic cooling poverty in the global south. *Nature Sustainability* [Internet]. May 22 2026;9(8):1266–76. Available from: <https://www.nature.com/articles/s41893-026-01845-4>
78. For example, see: Glaser J, Wegman DH, Arias-Monge E, et al. Workplace Intervention for Heat Stress: Essential Elements of Design, Implementation, and Assessment. Vol. 19, *International journal of environmental research and public health* [Internet]. 2022. p. 3779. Available from: <https://pubmed.ncbi.nlm.nih.gov/35409463/>; Al-Bouwarthan M, Quinn MM, Kriebel D, et al. Risk of Kidney Injury among Construction Workers Exposed to Heat Stress: A Longitudinal Study from Saudi Arabia. *International Journal of Environmental Research and Public Health* [Internet]. May 26 2020;17(11):3775. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC7312975/>; Masoud A, McKenna ZJ, Li Z, et al. Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology* [Internet]. March 1 2024;326(3):F499–510. Available from: <https://journals.physiology.org/doi/full/10.1152/ajprenal.00350.2023>
79. Bharadwaj, R, Karthikeyan, N, Abhilashi, et al. Too hot to work, too poor to rest: health and economic impacts of heat stress on informal workers in urban India [Internet]. 2026. Available from: <https://www.iiied.org/sites/default/files/pdfs/2026-07/22750iiied.pdf>
80. Nerbass FB, Moist L, Clark WF, et al. Hydration Status and Kidney Health of Factory Workers Exposed to Heat Stress: A Pilot Feasibility Study. Vol. 74 Suppl 3, *Annals of nutrition & metabolism* [Internet]. 2019. p. 30–7. Available from: <https://pubmed.ncbi.nlm.nih.gov/31203303/>; Venugopal V, Lennqvist R, Latha PK, et al. Occupational Heat Stress and Kidney Health in Salt Pan Workers. Vol. 8, *Kidney international reports* [Internet]. 2023. p. 1363–72. Available from: <https://pubmed.ncbi.nlm.nih.gov/37441492/>
81. CDC NIOSH Science Bulletin. Take Action Now to Prevent Heat-Related Illness at Work [Internet]. May 7 2021. Available from: <https://www.cdc.gov/niosh/bulletin/2021/heat-stress.html>

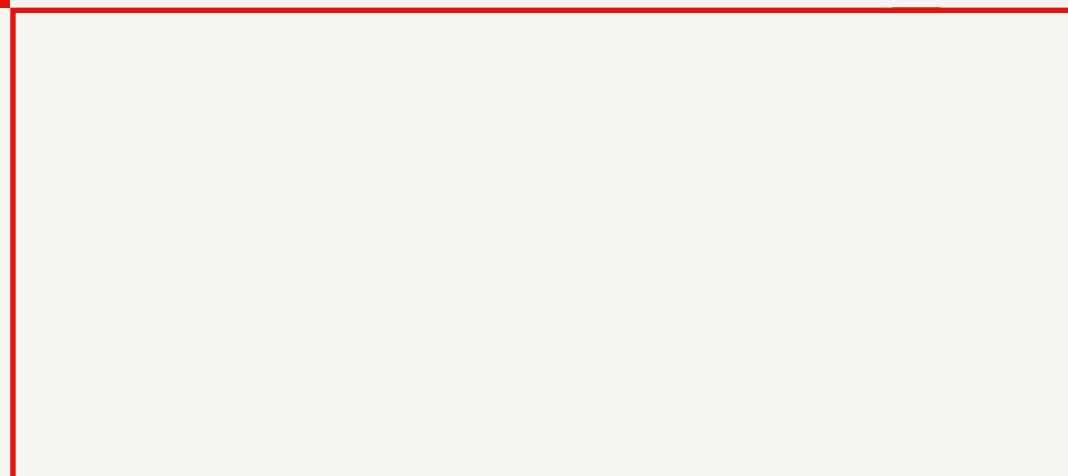
82. WHO. Reducing the burden of noncommunicable diseases through promotion of kidney health and strengthening prevention and control of kidney disease [Internet]. May 27 2025. Available from: https://apps.who.int/gb/ebwha/pdf_files/WHA78/A78_R6-en.pdf
83. KDIGO 2026 Clinical Practice Guideline for Acute Kidney Injury (AKI) and Acute Kidney Disease (AKD). Public Review Draft [Internet]. March 2026. Available from: <https://kdigo.org/wp-content/uploads/2026/03/KDIGO-2026-AKI-AKD-Guideline-Public-Review-Draft-March-2026.pdf>
84. The Telegraph. 'Island of Widows': The mystery disease killing sugarcane workers around the world [Internet]. 2019. Available from: <https://www.telegraph.co.uk/global-health/climate-and-people/island-widows-mystery-disease-killing-sugarcane-workers-around/>
85. Glaser J, Weiss I, CKDu: Strategies for Saving Lives Now. MEDICC Rev [Internet]. 2014;16(2):81–82. Available from: <https://doi.org/10.37757/MR2014.V16.N2.16>
86. Rutter CE, Njoroge M, Cooper PJ, et al. International prevalence patterns of low eGFR in adults aged 18–60 without traditional risk factors from a population-based cross-sectional disadvantaged populations eGFR epidemiology (DEGREE) study. Kidney International [Internet]. March 2025;107(3):541–57. Available from: [https://www.kidney-international.org/article/S0085-2538\(24\)00910-4/fulltext](https://www.kidney-international.org/article/S0085-2538(24)00910-4/fulltext)
87. Rutter CE, Njoroge M, Cooper PJ, et al. International prevalence patterns of low eGFR in adults aged 18–60 without traditional risk factors from a population-based cross-sectional disadvantaged populations eGFR epidemiology (DEGREE) study. Kidney International [Internet]. March 2025;107(3):541–57. Available from: [https://www.kidney-international.org/article/S0085-2538\(24\)00910-4/fulltext](https://www.kidney-international.org/article/S0085-2538(24)00910-4/fulltext)
88. Herrera-Valdés R, Almaguer-López MA, Orantes-Navarro CM, et al. Epidemic of Chronic Kidney Disease of Nontraditional Etiology in El Salvador: Integrated Health Sector Action and South-South Cooperation. Vol. 21. MEDICC review [Internet]. 2019. p. 46–52. Available from: <https://pubmed.ncbi.nlm.nih.gov/32335569/>
89. Wesseling C, van Wendel de Joode B, Crowe J, et al. Mesoamerican nephropathy: geographical distribution and time trends of chronic kidney disease mortality between 1970 and 2012 in Costa Rica. Vol. 72. Occupational and environmental medicine [Internet]. 2015. p. 714–21. Available from: <https://pubmed.ncbi.nlm.nih.gov/26199395/>
90. Sharma SK, Upadhyaya MK. Migrant Work and Kidney Health in Nepal: Prevention is Better than Cure. Vol. 5. Kidney360 [Internet]. 2024. p. 1563–5. Available from: <https://pubmed.ncbi.nlm.nih.gov/39141442/>
91. Aryal N, Regmi PR, Sedhain A, et al. A comparison of chronic kidney risk among returnee Nepalese migrant workers in the countries of the Gulf and Malaysia and non-migrants in Nepal: a population-based cross-sectional study. Vol. 27. BMC nephrology [Internet]. 2026. p. 263. Available from: <https://pubmed.ncbi.nlm.nih.gov/41851648/>
92. The Telegraph. 'Island of Widows': The mystery disease killing sugarcane workers around the world [Internet]. 2019. Available from: <https://www.telegraph.co.uk/global-health/climate-and-people/island-widows-mystery-disease-killing-sugarcane-workers-around/>
93. Chapman E, Haby MM, Illanes E, et al. Risk factors for chronic kidney disease of non-traditional causes: a systematic review. Rev Panam Salud Publica [Internet]. March 2019 14;43:e35. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6461065/>
94. Elinder C-G. Heat-induced kidney disease: understanding the impact. J Intern Med [Internet]. 2025;297(1):101–112. Available from: <https://pubmed.ncbi.nlm.nih.gov/39607397/>
95. Elinder CG. Heat-induced kidney disease: Understanding the impact. J Intern Med [Internet]. 2025;297(1):101–112. Available from: <https://pubmed.ncbi.nlm.nih.gov/39607397/>
96. Orantes-Navarro CM, Herrera-Valdés R, Almaguer-López M, López-Marín L, Vela-Parada XF, Hernández-Cuchillas M, et al. Toward a Comprehensive Hypothesis of Chronic Interstitial Nephritis in Agricultural Communities. Vol. 24. Advances in chronic kidney disease [Internet]. 2017. p. 101–6. Available from: <https://pubmed.ncbi.nlm.nih.gov/28284375/>
97. Glaser J, Wegman DH, Arias-Monge E, et al. Workplace Intervention for Heat Stress: Essential Elements of Design, Implementation, and Assessment. Vol. 19. International journal of environmental research and public health [Internet]. 2022. p. 3779. Available from: <https://pubmed.ncbi.nlm.nih.gov/35409463/>
98. Pan American Health Organization. Evidence for CKDnt being primarily an occupation-driven disease in Mesoamerica [Internet]. 2019. Available from: <https://iris.paho.org/server/api/core/bitstreams/bc058a7b-4b22-4071-931c-b833dcb836f/content>
99. Ekanayake EMDV, De Silva PMCS, Gunasekara TDKSC, et al. Prevalence of Chronic Kidney Disease of Uncertain Etiology Within Selected Farming Communities in Rural Sri Lanka. Can J Kidney Health Dis [Internet]. September 26 2023;10:20543581231199013. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC10524071/>
100. Wesseling C, Aragón A, González M, et al. Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua. BMJ Open [Internet]. December 2016;6(12):e011034. Available from: <https://bmjopen.bmj.com/content/6/12/e011034>
101. Al-Bouwarthan M, Quinn MM, Kriebel D, et al. Risk of Kidney Injury among Construction Workers Exposed to Heat Stress: A Longitudinal Study from Saudi Arabia. International Journal of Environmental Research and Public Health [Internet]. May 26 2020;17(11):3775. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC7312975/>
102. Wesseling C, Aragón A, González M, et al. Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua. BMJ Open [Internet]. December 2016;6(12):e011034. Available from: <https://bmjopen.bmj.com/content/6/12/e011034>
103. Keogh SA, Leibler JH, Sennett Decker CM, et al. High prevalence of chronic kidney disease of unknown etiology among workers in the Mesoamerican Nephropathy Occupational Study. BMC Nephrology [Internet]. July 7 2022;23(1). Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC9261054/>
104. Venugopal V, Lennqvist R, Latha PK, et al. Occupational Heat Stress and Kidney Health in Salt Pan Workers. Vol. 8. Kidney international reports [Internet]. 2023. p. 1363–72. Available from: <https://pubmed.ncbi.nlm.nih.gov/37441492/>
105. Li M, Zhang Y, Zhang Z, et al. Occupational heat exposure and chronic kidney disease risk under climate warming: a retrospective cohort study of petrochemical workers with mechanistic insights. Environ Health [Internet]. 2026. Available from: <https://doi.org/10.1186/s12940-026-01305-8>
106. Reule S, Ensrud K, Danko J, et al. Chronic Kidney Disease and Military Service in US Adults, 1999–2018. Fed Pract [Internet]. December 2023;40(12):404–411. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC1132105/>
107. Jayaweera JAAS, Joseph A. Assessment of healthiness among long term inhabiting army soldiers in dry zone of Sri Lanka. BMC Res Notes [Internet]. July 13 2018;11(1):474. Available from: <https://pubmed.ncbi.nlm.nih.gov/articles/PMC6045845/>
108. Grundstein A, Knox JA, Vanos J, et al. American football and fatal exertional heat stroke: a case study of Korey Stringer. Int J Biometeorol [Internet]. 2017;61(8):1471–1480. Available from: <https://pubmed.ncbi.nlm.nih.gov/28314926/>
109. Rojas-Valverde D, Olcina G, Gutiérrez-Vargas R, et al. Heat Strain, External Workload, and Chronic Kidney Disease in Tropical Settings: Are Endurance Athletes Exposed? Front Physiol [Internet]. November 21 2019;10:1403. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6881241/#B4>
110. Nagaraju R, Babu KR, Jakkam S, et al. Comparison of Chronic Kidney Disease Unknown Etiology (CKDu) Prevalence in Industrial Workforce Using Different eGFR Equations. J Occup Health Epidemiol [Internet]. 2025;14(2):108–16. Available from: <https://pdfs.semanticscholar.org/baac/9613858e5650ac346132716928ede28fc5b9.pdf>
111. Shi DS, Weaver VM, Hodgson MJ, et al. Hospitalised heat-related acute kidney injury in indoor and outdoor workers in the USA. Occupational and Environmental Medicine [Internet]. 2022;79:184–191. Available from: <https://oem.bmj.com/content/79/3/184>
112. Shi DS, Weaver VM, Hodgson MJ, et al. Hospitalised heat-related acute kidney injury in indoor and outdoor workers in the USA. Occupational and Environmental Medicine [Internet]. 2022;79:184–191. Available from: <https://oem.bmj.com/content/79/3/184>

113. Nerbass FB, Moist L, Clark WF, et al. Hydration Status and Kidney Health of Factory Workers Exposed to Heat Stress: A Pilot Feasibility Study. Vol. 74 Suppl 3, *Annals of nutrition & metabolism* [Internet]. 2019. p. 30–7. Available from: <https://pubmed.ncbi.nlm.nih.gov/31203303>
114. Elinder CG. Heat-induced kidney disease: Understanding the impact. *J Intern Med* [Internet]. January 2025;297(1):101–112. <https://pmc.ncbi.nlm.nih.gov/articles/PMC6065092/>
115. See, for example, Tamás V, Kocsor F, Gyuris P, et al. The Young Male Syndrome—An Analysis of Sex, Age, Risk Taking and Mortality in Patients With Severe Traumatic Brain Injuries. *Front Neurol* [Internet]. April 12 2019;10:366. <https://pmc.ncbi.nlm.nih.gov/articles/PMC6473461/>
116. WHO. Reducing the burden of noncommunicable diseases through promotion of kidney health and strengthening prevention and control of kidney disease [Internet]. May 27 2025. Available from: https://apps.who.int/gb/ebwha/pdf_files/WHA78/A78_R6-en.pdf
117. English version of text available at: https://medicreview.org/wp-content/uploads/2018/05/San_Salvador_English_online.pdf
118. WHO. Planning heat health action [Internet]. Available at <https://www.who.int/europe/activities/planning-heat-health-action>
119. WHO and WMO. Heatwaves and health: guidance on warning system development [Internet]. Available at <https://www.who.int/publications/m/item/heatwaves-and-health--guidance-on-warning-system-development>
120. GHIN. About our network [Internet]. Available from: <https://heathealth.info/about-us/>. Accessed 16 July 2026.
121. Stewart-Ruano A, Spriggs R, Lawrance EL, et al. A Critical Gap in Addressing Mental Health in Heat-Health Action Plans Worldwide. *Curr Environ Health Rep* [Internet]. May 26 2025;12(1):23. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12798820/>
122. See GHIN. Resource Library [Internet]. Accessed July 15 2026. Available from: <https://heathealth.info/resource-library/>
123. GHIN and United Nations Office for Disaster Risk Reduction and World Meteorological Organization. Extreme Heat Risk Governance Framework and Toolkit [Internet]. 2025. Available from: <https://www.undrr.org/media/112518/download?startDownload=20260510>
124. Quintana AV, Gilson L, Kovats S, et al. The implementation gap: Cross-sector management of heat-related health risks in Western Cape, South Africa. *PLOS Glob Public Health* [Internet]. October 29 2025;5(10):e0004699. <https://journals.plos.org/globalpublichealth/article?id=10.1371/journal.pgph.0004699>
125. Kriit H, Chen-Xu J, Semenza J et al. The 2026 Europe report of the Lancet Countdown on health and climate change: narrowing window for decisive health action. *The Lancet Public Health* [Internet]. 2026; 11, e386–e407. Available from: [https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667\(26\)00025-3/fulltext](https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(26)00025-3/fulltext); Rayner T, Smith E, Howarth C, et al. Advancing and Integrating Climate and Health Policies in the United Kingdom: Insights from National Stakeholders [Internet]. 2025. Available from: <https://tyndall.ac.uk/wp-content/uploads/2025/01/Advancing-Climate-Change-and-Health-Policies-in-the-UK-final.pdf>
126. Rio de Janeiro. Decreto Rio Nº 54740 de 28 de junho de 2024 [Internet]. July 1 2024. Available from: https://doweb.rio.rj.gov.br/apifront/portal/edicoes/imprimir_materia/1070470/6662
127. O Tempo Brasil. Governo lança painel de alerta para calor extremo em municípios [Internet]. June 30 2026. Available from: <https://www.otempo.com.br/brasil/2026/6/30/governo-lanca-painel-de-alerta-para-calor-extremo-em-municipios>
128. WMO. Strengthening early warnings across Eastern and Southern Africa through WISER ActionFirst in Africa initiative [Internet]. April 2026. Available at: <https://wmo.int/media/project-update/strengthening-early-warnings-across-eastern-and-southern-africa-through-wiser-actionfirstm-africa>
129. WMO. Strengthening early warnings across Eastern and Southern Africa through WISER ActionFirst in Africa initiative [Internet]. April 2026. Available at: <https://wmo.int/media/project-update/strengthening-early-warnings-across-eastern-and-southern-africa-through-wiser-actionfirstm-africa>
130. Huang Q, Ke L, Linfeng L, et al. Heatwave warnings mitigate long-term cardiovascular diseases risk from heat-related illness: a real-world prospective cohort study. *The Lancet Regional Health Western Pacific* [Internet]. 2025;55:101468. Available from: [https://www.thelancet.com/journals/lanwpc/article/PIIS2666-6065\(25\)00005-7/fulltext](https://www.thelancet.com/journals/lanwpc/article/PIIS2666-6065(25)00005-7/fulltext)
131. Chu C, Chen M, McCulloch C, et al. Patient Awareness of CKD: A Systematic Review and Meta-analysis of Patient-Oriented Questions and Study Setting. *Kidney Medicine* [Internet]. 2021. 3(4): 576–585. e1. Available from: <https://www.sciencedirect.com/science/article/pii/S2590059521001047?via%3Dihub>
132. Kidney Research UK. The public don't know the kidney basics [Internet]. March 2022. Available from: <https://www.kidneyresearchuk.org/2022/03/10/the-public-dont-know-the-kidney-basics/>
133. Khoshnaw LJ, Johnson RJ, Young SE. Ten tips on how to care for your CKD patients in episodes of extreme heat. *Clin Kidney J* [Internet]. May 24 2024;17(6):sfae156. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC1195633/>
134. Mohammed S, Nashwan A. Heat Stress and Kidney Injury: A Growing Concern Amidst Climate Change. *Kidney Medicine* [Internet]. 2026. 8(2): 101215. Available from: <https://doi.org/10.1016/j.xkme.2025.101215>
135. KDIGO 2026 Clinical Practice Guideline for Acute Kidney Injury (AKI) and Acute Kidney Disease (AKD). Public Review Draft [Internet]. March 2026. Available from: <https://kdigo.org/wp-content/uploads/2026/03/KDIGO-2026-AKI-AKD-Guideline-Public-Review-Draft-March-2026.pdf>
136. Bello AK, Johnson DW, Feehally J, et al. Global Kidney Health Atlas (GKHA): design and methods. *Kidney Int Suppl* (2011) [Internet]. 2017 Oct;7(2):145–153. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6341016/>
137. Neale EP, Middleton J, Lambert K. Barriers and enablers to detection and management of chronic kidney disease in primary healthcare: a systematic review. *BMC Nephrol* [Internet]. March 12 2020;21(1):83. Available from: <https://pubmed.ncbi.nlm.nih.gov/32160886/>
138. Ferrara P, Rozza D, Antonazzo IC, et al. Awareness and management of stage 3 chronic kidney disease among primary care practitioners in Italy: a nation-wide observational study. *J Nephrol* [Internet]. December 2025;38(9):2731–2742. Available from: <https://pubmed.ncbi.nlm.nih.gov/40849875/>
139. For an overview, see: Cervantes CE, O'Hara DV, Alvarez-Elias AC, et al. Expanding Kidney Care: How Nonphysician Health Workers Can Address the Global CKD Crisis. *Kidney International Reports* [Internet]. 2026. 11(3):103625. Available from: <https://www.sciencedirect.com/science/article/pii/S2468024925006114>; Novick TK, Cervantes L, Golestaneh L, et al. Proceedings of a Workshop to Promote Community Health Worker Interventions in Nephrology. *J Am Soc Nephrol* [Internet]. November 1 2023;34(11):1812–1818. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC10631597/>
140. Bellasi A, Di Lullo L, Di Iorio B. Chronic Kidney Disease: The Silent Epidemic. *J Clin Med* [Internet]. October 26 2019;8(11):1795. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6912263/>
141. Shlipak M, Tummalaipalli S, Boulware L, et al. The case for early identification and intervention of chronic kidney disease: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference. *Kidney International* [Internet]. 2020; 99, 34–47. Available from: [https://www.kidney-international.org/article/S0085-2538\(20\)31210-2/fulltext](https://www.kidney-international.org/article/S0085-2538(20)31210-2/fulltext)
142. Cusick MM, Tisdale RL, Chertow GM, et al. When to Start Population-Wide Screening for Chronic Kidney Disease: A Cost-Effectiveness Analysis. *JAMA Health Forum* [Internet]. November 1 2024;5(11):e243892. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11549659/>
143. Tangri N, Oh K, Choo J, et al. Inside CKD: Cost-Effectiveness of Multinational Screening for CKD. *Kidney International Reports* [Internet]. 2025; 10: 1087–1100. Available from: [https://www.kireports.org/article/S2468-0249\(25\)00045-2/fulltext](https://www.kireports.org/article/S2468-0249(25)00045-2/fulltext)
144. Sorensen CJ, Krisher L, Butler-Dawson J, et al. Workplace screening identifies clinically significant and potentially reversible kidney injury in heat-exposed sugarcane workers. *Int J Environ Res Public Health* [Internet]. 2020;17(22):8552. Available from: <https://doi.org/10.3390/ijerph17228552>

145. Hansson E, Wesseling C, Wegman D, et al. Point-of-care biomarkers for prediction of kidney function trajectory among sugarcane cutters: a comparative test accuracy study. *BMJ Open* [Internet]. 2022;12(1):e060364. Available from: <https://doi.org/10.1136/bmjopen-2021-060364>
146. Kulasooriya PN, Jayasekara KB, Nisansala T, et al. Utility of self-reported heat stress symptoms and NGAL biomarker to screen for chronic kidney disease of unknown origin (CKDu) in Sri Lanka. *Int J Environ Res Public Health* [Internet]. 2021;18(19):10498. Available from: <https://doi.org/10.3390/ijerph181910498>
147. Lees J, Zhang L, Anandh U, et al. Advances in the diagnosis and detection of chronic kidney disease. *The Lancet* [Internet]. 2026; 407: 2414-2428. Available from: [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(26\)00702-6/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(26)00702-6/fulltext)
148. Costa Rica. Ministerio de Salud y Ministerio de Trabajo y Seguridad Social. Reglamento para la prevención y protección de las personas trabajadoras expuestas a estrés térmico por calor (Decreto Ejecutivo N° 39147-S-TSS). San José: Diario Oficial La Gaceta. 2015. Available from: <https://www.mtss.go.cr/elministerio/despacho/decretos/Reglamento%20para%20la%20prevencion%20y%20proteccion%20de%20las%20personas%20trabajadoras%20expuestas%20a%20estres%20termico%20por%20calor.pdf>
149. Ministério do Trabalho e Emprego. Norma Regulamentadora No. 15 (NR-15). May 2025. Available from: <https://www.gov.br/trabalho-e-emprego/pt-br/acesso-a-informacao/participacao-social/conselhos-e-orgaos-colegiados/comissao-tripartite-partitaria-permanente/normas-regulamentadora/normas-regulamentadoras-vigentes/norma-regulamentadora-no-15-nr-15>
150. Nicaragua. Ley N°. 618: Ley General de Higiene y Seguridad del Trabajo. La Gaceta, Diario Oficial N°. 133. July 13 2007. Available from: [http://legislacion.asamblea.gob.ni/normaweb.nsf/\(\\$All\)/16624DBD812ACC1B06257347006A6C8C?OpenDocument](http://legislacion.asamblea.gob.ni/normaweb.nsf/($All)/16624DBD812ACC1B06257347006A6C8C?OpenDocument)
151. Jacklitsch B, Williams WJ, Musolin K, et al. NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments [Internet]. 2016. Available from: <https://www.cdc.gov/niosh/docs/2016-106/pdfs/2016-106.pdf>
152. See also: Schlader ZJ, Boswell T, Prince H, et al. A Rest-Shade-Hydration-Hygiene program reduces acute kidney injury and increases production at a sugar mill in Nicaragua, an economic analysis. *medRxiv* (pre-print) [Internet]; 2025. p. 2025.02.19.25322486. Available from: <https://pubmed.ncbi.nlm.nih.gov/40034750/>
153. Davids MR, Eastwood JB, Selwood NH, et al. A renal registry for Africa: first steps. *Clinical Kidney Journal* [Internet]. November 25 2015;9(1):162–7. Available from: <https://academic.oup.com/ckj/article/9/1/162/2462453>
154. African Association of Nephrology. Registry [Internet]. Available from: <https://afran.org/registry/>
155. Rajapurkar MM, John GT, Kirpalani AL, et al. What do we know about chronic kidney disease in India: first report of the Indian CKD registry. *BMC Nephrol* [Internet]. March 6 2012;13:10. Available from: <https://pubmed.ncbi.nlm.nih.gov/22390203/>
156. See: Consortium for the Epidemic of Nephropathy in Central America and Mexico (CENCAM) [Internet]. Available from: <https://cencam.net/>; CENCAM, Commented Summary report on available and published reports on Mesoamerican Nephropathy (MeN), Chronic Kidney Disease of unknown Cause (CKDu), CKDnT, and CINAC. 2026, <https://cencam.net/publications/>
157. For example, Mattson DL. Heat stress nephropathy and hyperuricemia. *Am J Physiol Renal Physiol* [Internet]. October 1 2018;315(4):F757-F758. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6230731/>; Garg R. Rising heat, failing kidneys: Heat stress nephropathy in climate crisis. *RMC Glob J* [Internet]. 2025;1:48–57. Available from: <https://rmcglobaljournal.com/rising-heat-failing-kidneys-heat-stress-nephropathy-in-climate-crisis/>
158. These recent articles do use the term: Hansson E, Lucas RAI, Glaser et al. Understanding Changes in Serum Creatinine During Work in Heat. *Kidney Int Rep* [Internet]. April 26 2025;10(8):2860-2863. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12348246/>; Seo SH, Go S, Jeong Y. Environmental Heat and Renal Health Across Cosmopolitan Populations: A Scoping Review Focused on Sex-Specific Vulnerability. *International Journal of Public Health* [Internet]. March 25 2026;71. Available from: <https://www.sspj-journal.org/journals/international-journal-of-public-health/articles/10.3389/ijph.2026.1609356/full>
159. Kulasooriya PN, Jayasekara KB, Nisansala T, et al. Utility of Self-Reported Heat Stress Symptoms and NGAL Biomarker to Screen for Chronic Kidney Disease of Unknown Origin (CKDu) in Sri Lanka. *Int J Environ Res Public Health* [Internet]. October 6 2021;18(19):10498. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC8507708/>

While every effort has been taken to verify the accuracy of this information, Economist Enterprise cannot accept any responsibility or liability for reliance by any person on this report or any of the information, opinions or conclusions set out in this report.

The findings and views expressed in the report do not necessarily reflect the views of the sponsor.



London

The Adelphi
1-11 John Adam Street
London WC2N 6HT
United Kingdom
Tel: (44) 20 7830 7000
Email: london@economist.com

Geneva

Rue de l'Athénée 32
1206 Geneva
Switzerland
Tel: (41) 22 566 2470
Fax: (41) 22 346 93 47
Email: geneva@economist.com

Washington DC

1920 L Street
NW Suite 500
Washington DC
20002
United States
Email: americas@economist.com

New York

750 Third Avenue
5th Floor
New York, NY 10017
United States
Tel: (1.212) 554 0600
Fax: (1.212) 586 1181/2
Email: americas@economist.com

Dubai

Office 1301a
Aurora Tower
Dubai Media City
Dubai
Tel: (971) 4 433 4202
Fax: (971) 4 438 0224
Email: dubai@economist.com

Hong Kong

1301
12 Taikoo Wan Road
Taikoo Shing
Hong Kong
Tel: (852) 2585 3888
Fax: (852) 2802 7638
Email: asia@economist.com

Singapore

8 Cross Street
#23-01 Manulife Tower
Singapore
048424
Tel: (65) 6534 5177
Fax: (65) 6534 5077
Email: asia@economist.com