Exploration of Digestive Diseases

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Climate change and liver diseases: from infectious disease dynamics to metabolic and malignant liver disorders, and sustainable healthcare solutions

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Abstract

Climate change (CC) affects our health in ways especially when it comes to liver diseases. Rising temperatures and changing weather patterns are altering the spread and severity of liver diseases. CC can affect health, especially liver diseases, in direct and indirect ways. Hepatic infections such as viral hepatitis and schistosomiasis, metabolic dysfunction-associated steatotic liver disease (MASLD), hepatocellular carcinoma, and acute on chronic liver failure (ACLF) are examples. The movement of infected individuals from areas where diseases are endemic, prompted by ecological disasters, introduces these diseases to previously unexposed regions. CC serves as an early warning for shifts and the necessity to re-evaluate hepatic diseases, which is crucial for health policymakers. Ambient temperature and its variability have a major influence on the pathogenesis of MASLD, demonstrating nonlinear exposure–response relationships. Long-term temperature exposure follows a reverse J-shaped pattern, while temperature variability shows a U-shaped association, with both extremes independently increasing disease susceptibility. Prolonged exposure to cold and fluctuations in temperature could worsen various liver diseases. Gaining a deeper insight into these CC-related risks for our patients and practice is essential to optimize their care both now and in the warmer temperatures ahead. Incorporating climate resilience into public health initiatives may aid in alleviating the growing prevalence of liver diseases linked to CC. Aside from increasing awareness, which should take precedence, there is a pressing need to investigate innovative ways to frame the educational message and eliminate financial incentives that contribute to environmental damage. Common climate strategies for healthcare systems include reducing and managing waste, utilizing cleaner and less energy, offering and endorsing planet-friendly food options, and addressing transportation issues related to

accessing healthcare facilities, such as transitioning in-person appointments to virtual consultations when possible, encouraging green-endoscopy practices, and participating in conferences virtually can be beneficial.

Keywords

climate change, liver infectious diseases, parasitic liver diseases, metabolically dysfunction-associated steatotic liver disease, hepatocellular carcinoma, acute on chronic liver failure (ACLF)

Introduction

The swift industrial and economic growth experienced globally since the Industrial Revolution has been linked to a significant rise in the production of greenhouse gas (GHG), resulting in global warming. This global warming is triggering such drastic climate change (CC) that many consider it a threat to our very existence [1].

CC denotes enduring changes in temperature and weather patterns [2]. In October 2021, the World Health Organization (WHO) [3] recognized CC as "the foremost health challenge confronting humanity". Since 1900, annual global mean temperatures have increased by 1.1°C, mainly in the past 50 years [4]. By the end of this century, expected warming is expected to reach up to 2.5°C to 2.9°C [5]. The international community must limit the increase in temperature to 1.5°C to prevent disastrous health consequences [6]. Since the Earth functions as an interconnected system, a rise in temperature marks just the start of alterations in one area that can trigger changes in all others. CC is linked to a rise in extreme weather phenomena, such as severe droughts, water shortages, intense wildfires, rising ocean levels, flooding, melting ice caps, devastating storms, and diminishing biodiversity. Human actions have been the primary cause of CC, mainly resulting from the combustion of fossil fuels such as coal, oil, and gas. The pressing need to address the effects of CC is commonly referred to as the climate crisis [7]. GHGs must be cut in half by 2030, and net-zero carbon dioxide (CO_2) emissions must be reached by 2050 in order to minimize temperature rise [8, 9]. The costs of doing nothing will be much outweighed by the economic advantages of achieving net-zero GHG emissions [10]. GHGs are substances that produce the greenhouse effect, a phenomenon where heat from the sun is trapped in Earth's atmosphere and unable to escape into space. CO_2 is one of these gases; human activity is responsible for more than 64% of global warming [11]. Because CO_2 can linger in the atmosphere for decades without dissipating, its effects on the ecosystem and human health are long-lasting. The majority of gases that cause CC are referred to as short-lived climate pollutants (SLCPs) because, in contrast to CO_2, they do not remain in the atmosphere for very long. However, they have a greater warming impact than CO_2, which seriously harms the ecosystem. One of these gases, ozone, affects the climate more significantly than previously believed. It remains in the atmosphere for twelve years. Compared to CO_2, its warming effect is 81.2 times stronger over a 20-year period and 28 times stronger over a 100-year period [12].

Light outdoor exercise carries a moderate risk of heat stress, with an annual rise of 27.7% compared to 2000 [13], and reduces labor productivity [14, 15] in addition to endangering workers' health [16]. Up to 512 billion potential work hours were lost in 2023 as a result of heat exposure, which is 49% more than the average from 1990 to 1999. Of these, 63% were lost in the agricultural sector [13]. Nighttime temperatures brought on by CC are linked to both quantity and quality of sleep disturbances [17].

Methodology

A systematic literature search in PubMed MeSH and Google scholar searches were done. Full-text articles published in English and articles providing an English abstract were reviewed. The following terms were used: "climate change, global warming" OR "climatic change" OR "atmospheric change" OR "meteorological change" AND "health map" OR "emerging disease" OR "reemerging disease" OR "communicable disease" OR "non-communicable disease" OR "infectious disease" OR "endemic disease" OR "epidemic disease". We also manually examined the reference lists to identify additional relevant studies.

Vulnerable groups

Children and the elderly: Heatwaves pose a serious health risk, particularly to the elderly, small children, and those with underlying chronic renal, respiratory, or cardiovascular conditions [18]. Due to their susceptibility to environmental stressors and undeveloped biological defenses for immunological protection, DNA repair, and detoxification, children under the age of five suffer greatly [19]. Malnutrition in children is predicted to rise by 20% by 2050, impacting an extra 25 million kids. This will seriously impede efforts to reduce malnutrition among children [20]. However, compared to 1990–2000, heat-related mortality among adults over 65 has increased by 85%, above the predicted 38% increase in the absence of temperature changes. These deaths are expected to spike by 370% by 2041–2060 and 683% by 2081–2100 if temperatures rise by 2°C [21].

Gender inequalities

Women may be twice as likely as men to die from heat-related causes. Food insecurity and mortality rates are significantly greater in low-income households [22]. When food is scarce, women and girls tend to eat last and skip meals. In addition to impeding women's access to maternity and reproductive health care, CC affects pregnancy outcomes by altering temperature, nutritional status, and infectious illness risk [23].

Migration

One significant mechanism for the quick spread of infectious diseases is the movement of impacted workers from endemic contaminated areas as a result of the CC disasters to other virgin areas. Furthermore, it was discovered that untreated and undertreated liver disorders were present in the immigrant population [24]. There are currently 281 million foreign migrants among the more than 1 billion people on the move [25]. "Environmental migrants" are individuals or groups who are compelled to relocate either temporarily or permanently, either domestically or internationally, as a result of unfavorable environmental changes [26]. About 25% of all chronic HBV infections in the region are caused by people who migrate from endemic countries to the European Union/European Economic Area (EU/EEA) [27].

Region-specific effect

People around the world are unequally affected by CC [28]. Africa, South and Central America, and Asia experienced the highest number of days of health-threatening temperatures attributable to CC. Africa experienced the biggest increase in a heat-related mortality rate since 2000–2005. Recently, Europe had the highest rate of heat-related mortality 2017–2022 [17, 28, 29].

Given the reality of CC, its impact on the development of liver disease is increasingly recognized. It is important to understand the potential impact of CC on our patients and consider what we can do to impact the resultant climate crisis.

Impact of CC on liver diseases

Globally, liver diseases are responsible for 2 million deaths annually; however, the number is still growing [30]. CC potentially influences all determinants of liver disease and consequently contributes to the anticipated increase in the global burden of liver disease [31]. CC can affect health directly or indirectly (Figure 1).

The physiological effects of excessive heat are more likely to affect those with chronic illnesses [33].

Extreme heat physiologically results in hepatic cell necrosis, ischemia, acute liver damage, and, in severe cases, acute liver failure [34].

Mental health is said to be negatively impacted by the climate issue. Alcohol-related viral hepatitis may develop as a result of substance abuse, which has been linked to anxiety and stress [35]. The three most prevalent causes of liver disease are viral hepatitis, alcohol-related liver disease, and metabolic dysfunction-associated steatotic liver disease (MASLD), all of which are vulnerable to the effects of CC.

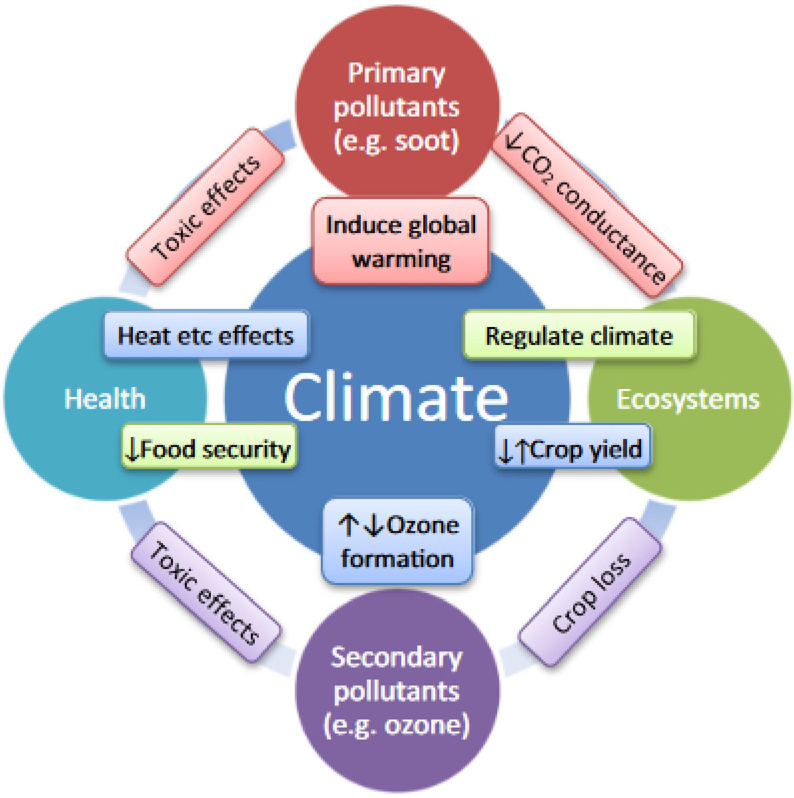

Figure 1. Climate and air quality interactions and direct and indirect effects on health. Reprinted from [32].

Although the precise processes are yet unknown, air pollution is linked to the development of cirrhosis, chronic liver damage, and steatotic liver disease [36]. Additionally, a possible connection between rising ambient temperatures and biliary tract disease admissions has been found; however, the underlying processes are yet unknown [37].

Conversely, energy use, medical waste, and transportation emissions from healthcare systems—including liver units—contribute significantly to CC [38]. Unused medications at home are estimated to constitute 2 out of 3 prescription medications costs $2–5 billion in the United States alone [39].

The quantity of CO_2 we emit as a result of our activities is known as our carbon footprint. The carbon footprint of the healthcare industry contributes significantly to global CO_2 emissions—more than 4.4% [40, 41]. About 45% of emissions in endoscopy services are related to staff and patient transportation, and 32% are caused by the manufacture and disposal of medical equipment [42]. 1–2% of all urban waste is made up of healthcare waste (HCW) [43], of which 15% is deemed hazardous. The globe would be headed toward a potentially disastrous 2.7°C warming if the existing policies and practices are maintained [44]. Therefore, efforts to lower GHG emissions are crucial to safeguard people's health, survival, and well-being in every nation and provide immediate and long-term health advantages [45].

Individual liver diseases

Infectious diseases

Mora and his colleagues in 2022 [46] found that 58% of infectious diseases confronted by humanity worldwide have been at some point aggravated by climatic hazards, and 16% were at times diminished.

Vector-borne diseases (VBDs)

The seasonality, transmission resilience, and geographic distribution of VBDs will all be altered by CC [47]. Dengue and Rift Valley hemorrhagic fever are two VBD epidemics that are more likely to occur [48]. *Aides*, *Culex*, and *Anopheles* spp. are among the mosquito species that proliferate quickly due to the CC, which might result in hepatic viral disorders such as dengue, yellow fever, Rift Valley hemorrhagic fever, chikungunya (CHIKV), and Zika [49, 50]. As CHIKV outbreaks moved from the Indian Ocean to Europe, where they were reported in Italy and France, human and vector movements may also have an impact on these viral illnesses [51, 52].

In 2023, 5 million dengue cases were reported worldwide [53]. Due to improved climatic circumstances, greater human movement, and urbanization, the prevalence of dengue has dramatically grown during the past 20 years [54–58]. Every year, severe dengue is thought to kill 40,000 people [59]. Nonetheless, the death rate can be lowered to less than 1% with proper medical care and prompt intervention [53]. Comparable patterns were also noted for the CHIKV and Zika viruses' propensity for transmission.

Another illustration of the impact of CC is malaria. Increased rainfall and humidity have an impact on mosquito survival and reproduction, which causes infectious sporozoites to develop quickly in the mosquitoes [60]. Both the highlands of Colombia and Ethiopia are examples of increased spread due to high-elevation temperature [61, 62]. Plasmodium falciparum may now spread across an additional 17.1% of the world's geographical area, while Plasmodium vivax can spread over an additional 21.8%. CC has expanded suitable land for Plasmodium falciparum by 17.1% and Plasmodium vivax by 21.8%. However, in some endemic regions, transmission duration has decreased due to temperatures exceeding parasite survival thresholds [63].

Humans can contract the deadly neurological disease caused by the West Nile virus, which is spread by mosquitoes [64]. The virus is present all over the planet, and in some parts of the world, its range is growing [65]. Between the 1960s and this year, there was a 4.3% increase in the temperature at which the West Nile virus may spread.

A new era of infectious illnesses is upon us, marked by outbreaks of endemic, re-emerging, and emerging pathogens [66]. According to a recent survey, the most urgent and growing infection concerns seen by healthcare personnel in low-resource settings are VBDs (mostly dengue and malaria), TB, and HIV/AIDS, with poverty, socioeconomic factors, and rising treatment resistance as the main causes [67].

Water and food-borne infectious diseases

Water-borne disease transmission potential is affected by temperature changes and water salinity [68]. As water temperatures rise, they become more suitable for *Vibrio vulnificus* (*V. vulnificus*), a gram-negative bacterium that can cause fatal sepsis in patients with chronic illness, particularly liver disease [69]. While this is a low-incidence human pathogen, it has a high fatality rate of 18–50%. As outlined by Archer et al. [70], analysis of a 30-year database of *V. vulnificus* infections showed cases rising along with the Atlantic coastline and extending northward in a non-linear progression. Vibriosis cases increased by 13.5% from the previous record high in 2022. *V. vulnificus* can be found in brackish water. Patients with cirrhosis should avoid eating raw seafood (especially oysters) and exposing any open wounds to brackish water.

Hepatitis A and E viral infection incidence was increasingly recorded in China after floods in the year 2010 and is expected to increase by the year 2030 [71]. The ongoing outbreak of hepatitis E infection in South Sudan is a prime example [72].

Parasitic diseases

Fasciola hepatica is a sheep liver fluke that is transmitted to humans after ingestion of raw infected liver. It needs a wet and mild warm climate [73, 74]. Global warming makes the environment more suitable for the growth and survival of the infective stage and intermediate host, increasing the prevalence of infection [75]. Unexpected outbreaks of schistosomiasis and fascioliasis in the UK highlight the northward expansion of tropical parasitic diseases [76, 77].

Schistosomiasis and CC

The consequences of changing land use, an expanding human population, and subsistence livelihoods can interact in unanticipated ways with the impact of CC on schistosomiasis. It is difficult to predict how global CC may affect schistosomiasis [78, 79].

The outbreak of Schistosoma infection among swimmers in the Cavu River in Corsica, a French Mediterranean island, is believed to have been brought on by human movement and subsequent river contamination by parasite eggs that settled locally in vulnerable intermediate host snails and circulated for multiple seasons. The geographic range of schistosomiasis transmission does not include this location. It turns out that Schistosomiasis is hyperendemic in the lower basin of the Senegal River, where it started. As the world warms, there are worries that the range of Schistosomiasis may expand [80].

Schistosoma haematobium is predicted to decline under future climatic conditions in Africa, where appropriate locations are close to the equator [78]. There are worries about the spread of urogenital schistosomiasis into regions with cooler climates, such as the highlands of Ethiopia and South Africa, where the existence of suitable snail species and a lack of access to clean water are anticipated.

Schistosomiasis in China is expected to spread northward by 2100, according to studies conducted throughout Asia. However, this would make the mountainous areas of Sichuan province, where schistosomiasis is already common, unsuitable for snail rearing, hence decreasing the spread of the disease [81].

Nowadays, the northeast of Brazil is where the majority of Schistosomiasis cases in America occur [82]. Warming may increase the number of favorable habitats for transmission in the southeastern region, which is at the climatic margin for snail survival [83].

Because of this, it is anticipated that the spread of schistosomiasis will decline in central tropical Africa as temperatures will rise above the critical thermal maximum of snails. On the edges of the colder range, where temperatures are now too low for transmission, transmission is expected to increase.

MASLD and CC

The frequency of MASLD has alarmingly increased from 25.5% before 2005 to 37.8% in recent years, with current estimates at 32.4% [84, 85]. Recent evidence reveals that environmental factors play a crucial but underexplored contribution to the pathophysiology of MASLD. MASLD epidemic and the acceleration of the climate crisis go hand in hand, in addition to undernutrition and obesity [86]. Food insecurity in vulnerable locations worsens as a result of CC's rising impacts on agriculture, society, and the economy [87]. This is expected to induce obesity and contribute to excessive consumption of refined foods, which could raise the global burden of liver disease related to MASLD [88, 89]. A key component of managing liver disease, particularly in people with MASLD, is optimal diet. However, people with cirrhosis frequently suffer from malnutrition, which is particularly prevalent in those who are food insecure [90]. Sedentary behavior is a significant risk factor for MASLD [91]. Provocation of oxidative stress and stimulation of inflammatory responses impair hepatic metabolism and increase hepatic triglycerides and cholesterol, thereby fostering MASLD [92]. Microcystins (a hepatotoxic by-product of blue-green algae, which are increasing due to CC, and which can contaminate drinking water and swimming sites) can lead to progressive MASLD [93] (Figure 2).

A solid argument that ambient temperature variability (TV) functions as a harmful environmental driver of MASLD was recently presented by Wang et al. [94] in a nationwide investigation in 2026, showing nonlinear exposure-response correlations. A U-shaped relationship for TV, where both low and high unpredictability independently increased susceptibility, and a reverse J-shaped curve for long-term temperature exposure, where extreme cold conferred the highest MASLD risk. They were able to place these national findings in China into a larger international perspective by integrating global burden of disease (GBD) data, providing supportive but not causal evidence that comparable patterns may develop across varied climatic zones. They propose that TV could be an independent risk factor for MASLD, especially in areas where extreme and frequent temperature changes are expected [95]. They emphasize that when assessing environmental factors that contribute to liver illness, it is important to take into account both the absolute temperature and its variability. Mechanistically, exposure to cold can cause hepatic de novo lipogenesis [96], whereas television interferes with circadian metabolic cycles, aggravating oxidative stress and inflammation [97, 98]. Due to increased oxidative stress and hepatic inflammation

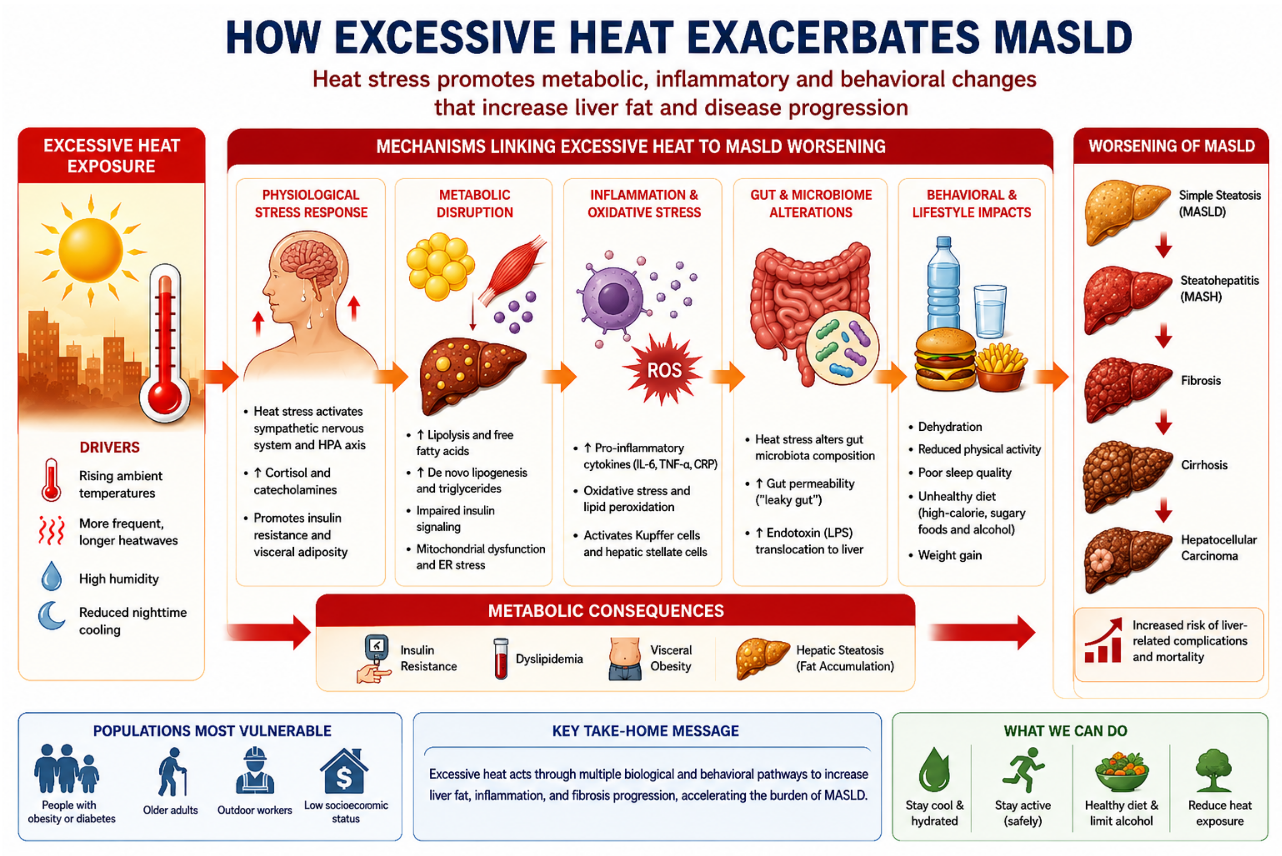

Figure 2. How excessive heat exacerbates metabolic dysfunction-associated steatotic liver disease (MASLD).

brought on by exercise in unfavorable settings, people with high levels of physical activity were more susceptible to MASLD in extreme weather conditions [99]. The dangers of obesity and MASLD were exacerbated by low TV exposure, which was more strongly linked to MASLD in the obese, whereas high TV exposure was more harmful to normal-weight people [100]. Incorporating environmental variables into MASLD prevention initiatives may help reduce the increasing burden of chronic liver disease by improving early identification and informing tailored therapies meant to mitigate the negative health impacts of CC. They highlight the dual problem of climate adaptation: worldwide initiatives to reduce rising temperatures must coexist with region-specific methods (such as cold mitigation in temperate zones). The growing MASLD pandemic amid CC may be lessened by including temperature resilience into public health systems.

Hepatocellular carcinoma (HCC)

Increased aflatoxin production by fungi in the setting of warming climes is anticipated to be related to increased primary liver cancer rates [101]. Given the increase in liver cancer incidence in the face of decreases in known risk factors in Australia, the possible influence of environmental changes has been investigated. Gan and his colleagues [102] reported higher liver cancer risk in the equatorial region and tropical regions, supporting the relation to CC.

Plastic waste made from fossil fuels is reportedly carcinogenic, and microplastics have been detected in human liver [103]. Pedersen et al. [104] in 2017 reported an association between cancer and elemental components such as sulphur, silicon, nickel, and iron.

Acute on chronic liver failure (ACLF)

Lin et al. [105] reported low temperature and high humidity as risk factors for ACLF. The highest prevalence of ACLF was observed in January, followed by July. Rainfall and temperature change did not affect the incidence of ACLF. It's unclear if weather variations directly cause ACLF pathology or if they have an impact on a secondary factor that raises the occurrence of ACLF. Temperature and humidity measurements may not fully account for the impacts of other seasonal elements, such as vitamin D and melatonin from exposure to light [106]. Hepatocyte dysfunction has been linked to hyperthermia, which can also cause mitochondrial dysfunction and decreased oxidative phosphorylation [107]. A recent multicenter clinical research study found no effect in reducing brain swelling or improving the survival rate of patients with acute liver failure, despite the fact that therapeutic hypothermia has been employed as a method primarily to reduce intracranial hypertension in patients with acute liver failure [108]. Precipitation decreased hospitalization rates, although both hot and cold temperatures raised the risk of bacterial infections.

There is an urgent need to better understand the liver carbon footprint, to allow adaptation and mitigation strategies to be put in place.

Strategic goals and objectives

Creative solutions to minimize waste-related costs and negative environmental impacts while preserving patient care and scientific advances are a priority. The utmost target to be emphasized is primary prevention and early diagnosis [29, 109]. Ninety per cent of liver disease is potentially preventable in Western populations [110] (Figure 3).

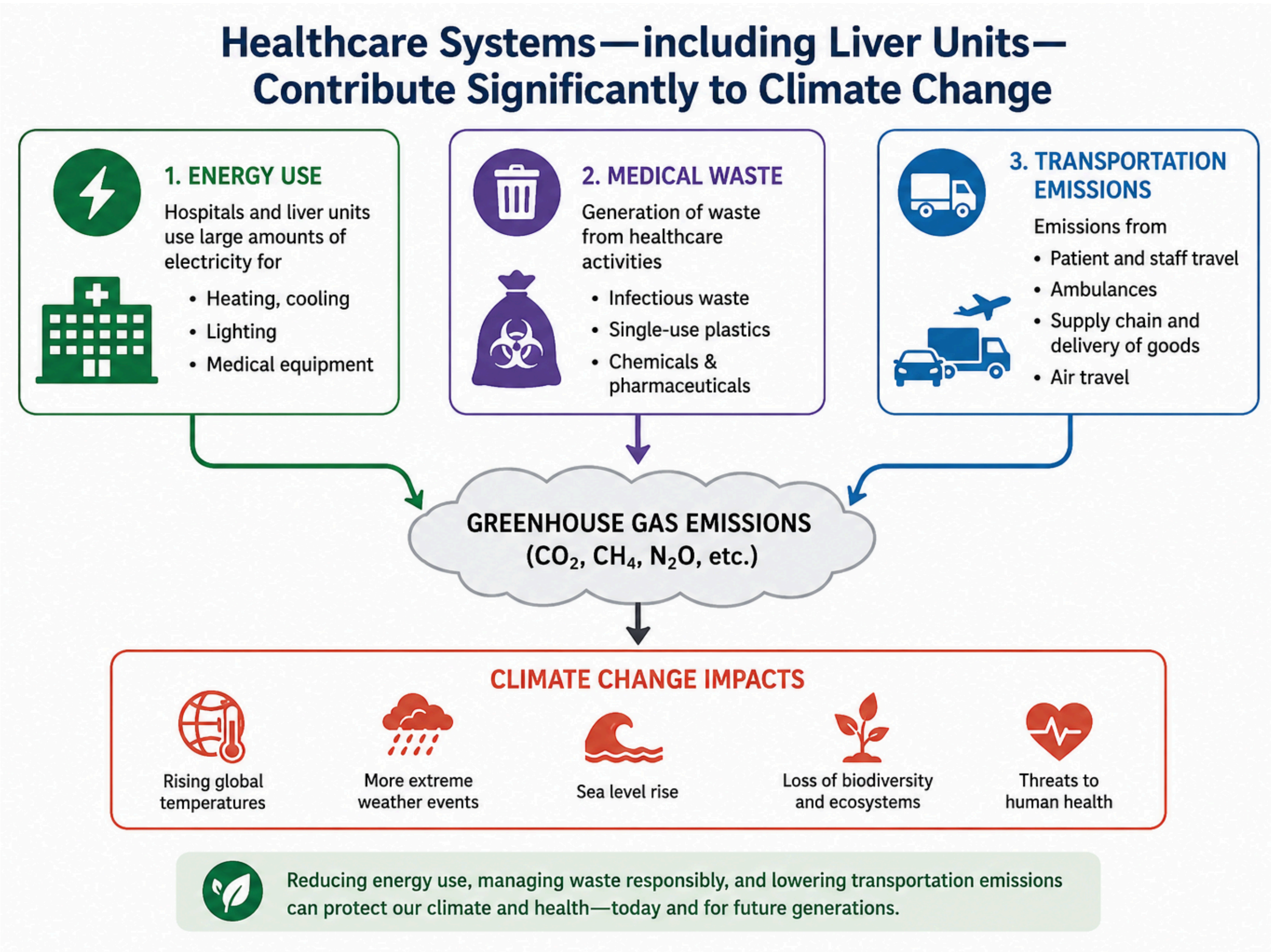

Figure 3. Health care systems, including liver units, contribute significantly to climate change.

A strategy to prevent alcoholic liver disease and reduce hospital admissions is an example of reducing GHG. Recent reports have shown a 4% decrease in alcohol-related hospital admissions, causing a positive environmental impact [111].

In order to lower costs and enhance results in the final year of life, Hudson and his colleagues [112] (2018) advise broader implementation of day-case models of care. They discovered that compared to patients receiving unplanned treatment, a specialized paracentesis service, patients with liver cirrhosis who visited a day case service had nearly 17 fewer hospital bed days.

To develop criteria for patient follow-up and encourage remote contact and use of noninvasive testing is important to decrease GHG emissions.

Plant-based diets, as opposed to red meat and ultra-processed foods, have lower carbon footprints than a typical Western diet and are estimated to be associated with a reduction in GHG emissions by up to 84% [113] and a lower risk of MASLD [114]. Regular exercise reduces the incidence of fatty liver [115]. If one person changed a single trip per day from driving to cycling, this would reduce that individual's carbon footprint by approximately 0.5 tons over 1 year [116].

Healthcare providers can promote and teach healthy lifestyle practices, including "planetary health diets", as proposed by the EAT-Lancet Commission: "Food is the single strongest lever to optimize human health and environmental sustainability on earth" [117].

"Greening" operating rooms, which generate up to 30% of a hospital's total waste and consume 3–6 times more energy per square foot than other parts of the hospital [118], with anesthesia gases making up more than 50% of the carbon footprint of surgical procedures [119].

The concept of a more sustainable future for endoscopy has been well promoted by the "Green Endoscopy Group" [120], motivated by the inconvenient observation that endoscopy is the third highest source of waste in a typical hospital [121]. A typical endoscopic treatment produces 2.1 kg of trash on average [122]. The traditional sustainability philosophy of "reduce, reuse, recycle" must be applied; cutting back on pointless procedures, which can account for up to 56% of upper GI endoscopies and between 23% and 52% of colonoscopies, can drastically reduce carbon footprints [123]. Inappropriate endoscopies produce 3,500–4,700 metric tons of CO_2 per year in Italy [124] and 30,804 metric tons of CO_2 per year throughout Europe [125]. Rationalizing the usage of specimen pots is another crucial step in lowering the carbon footprint of endoscopy, since the histological processing of tissue samples accounts for 36% of emissions [126].

ESGE suggests against the routine use of single-use devices and proposes using reusable alternatives instead of disposables. Last but not least, any waste should be recycled. In the endoscopy unit of a university hospital, these measures could collectively reduce carbon emissions by 18.4% [126].

In addition to endoscopy, alternative diagnostic techniques include intestinal ultrasound in place of colonoscopies [127]; fecal calprotectin may prevent needless endoscopic procedures if the likelihood of IBD is low, and instruments like FibroScan have less of an impact on the environment than repeated endoscopy and liver biopsies for cirrhosis and varices detection [125]. In order to minimize needless endoscopies, the Baveno VII consensus suggests estimating variceal risk using transient elastography and platelet counts [128].

Globally, the health industry is a major contributor to GHG emissions; in the US, for instance, it is responsible for 8.5% of total carbon emissions [129]. In the US healthcare system, waste is projected to cost about 25% of overall health care spending [130].

Examples of low-carbon alternatives and sustainable services in hepatology include telemedicine "virtual" consultations, which have become more popular since the start of the COVID-19 pandemic and can lead to significant carbon savings [131, 132], and outpatient, unsedated, ultrathin endoscopy, which can be performed during a routine clinic visit [133]. The downscaling of in-hospital liver care in one center resulted in lower patient satisfaction and higher liver-related mortality; thus, enthusiasm for telemedicine needs to be tempered with prudence [134]. To encourage a comprehensive and health-focused response to the dangers posed by CC, much work remains.

Limitations

Most of the studies dealing with CC and liver diseases are observational, with no confirmed causal mechanism relationship. In most cases, the data are uneven and vary from one region to another. The conclusions vary according to the included personnel characteristics and age group. Also, ethnicity affects the CC effects.

Conclusions

As an early warning system for hepatic health issues, CC may be crucial for health decision-makers. Planning solutions for CC adaptation and mitigation can make use of it. Many hepatic conditions, particularly infectious liver illnesses such as viral hepatitis, MASLD, ACLF, and HCC, could be made worse by prolonged exposure to CC. Clinicians should take into account the movement of infected patients from their endemic locations as a result of their diagnosis, as well as the knowledge that CC is a risk factor for a number of liver illnesses. Apart from increasing awareness, which ought to be the first objective, it is imperative to investigate new ways to frame the educational message and eliminate financial incentives that encourage environmental damage. Reducing and managing waste, using less and cleaner energy, offering and promoting foods that are good for the environment, and handling transportation to and from healthcare facilities are common climate solutions for healthcare systems.

Abbreviations

ACLF: acute on chronic liver failure

CC: climate change

CHIKV: chikungunya

GBD: global burden of disease

GHG: greenhouse gas

HCC: hepatocellular carcinoma

MASLD: metabolic dysfunction-associated steatotic liver disease

TV: temperature variability

V. vulnificus: *Vibrio vulnificus*

VBDs: vector-borne diseases

Declarations

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During the preparation of this work, authors used ChatGPT for the creation of Figure 2. After using ChatGPT, authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Author contributions

MTE: Conceptualization, Data curation, Methodology, Supervision, Writing—original draft, Writing—review & editing. MHH: Conceptualization, Formal analysis, Visualization, Writing—original draft, Writing—review & editing. YAA: Software, Validation, Writing—original draft, Writing—review & editing. EAT: Methodology, Validation, Writing—original draft, Writing—review & editing. GMEL: Data curation, Supervision, Writing—original draft, Writing—review & editing. HMAT: Methodology, Project administration, Software, Writing—original draft, Writing—review & editing. AAELR: Formal analysis, Visualization, Writing—original draft, Writing—review & editing. MDELT: Data curation, Supervision, Validation, Writing—original draft, Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Consent to participate

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Consent to publication

Not applicable.

Availability of data and materials

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References

1. Romanello M, McGushin A, Di Napoli C, Drummond P, Hughes N, Jamart L, et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet. 2021;398:1619–62. [DOI] [PubMed] [PMC]
2. Ribeiro T, Macedo G. Climate change and liver disease: a mini review. Front Gastroenterol (Lausanne). 2024;3:1334877. [DOI] [PubMed] [PMC]
3. COP26 special report on climate change and health: the health argument for climate action [Internet]. WHO; c2026 [cited 2025 Dec 3]. Available from: https://www.who.int/publications/i/item/9789240036727
4. Climate change 2022: impacts, adaptation and vulnerability [Internet]. [cited 2025 Dec 3]. Available from: https://www.ipcc.ch/report/ar6/wg2/
5. Emissions pathways to 2011 [Internet]. [cited 2025 Dec 3]. Available from: https://climateactiontracker.org/global/emissions-pathways/
6. Intergovernmental Panel on Climate Change (IPCC), editor. Climate Change 2022—Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2022.
7. UN75: Shaping our future together [Internet]. [cited 2025 Dec 16]. Available from: https://www.un.org/en/un75/finalreport
8. Meinshausen M, Lewis J, McGlade C, Gütschow J, Nicholls Z, Burdon R, et al. Realization of Paris Agreement pledges may limit warming just below 2°C. Nature. 2022;604:304–9. [DOI] [PubMed]
9. Matthews HD, Wynes S. Current global efforts are insufficient to limit warming to 1.5°C. Science. 2022;376:1404–9. [DOI] [PubMed]

10. Romanello M, Walawender M, Hsu SC, Moskeland A, Palmeiro-Silva Y, Scamman D, et al. The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action. Lancet. 2024;404:1847–96. [DOI] [PubMed] [PMC]
11. Exposure to household air pollution for 2017 [Internet]. [cited 2025 Dec 16]. Available from: https://cdn.who.int/media/docs/default-source/air-pollution-documents/air-quality-and-health/2017_hap_exposure_results_final.pdf?sfvrsn=3e6daedf_3
12. Mar KA, Unger C, Walderdorff L, Tim Butler T. Beyond CO_2 equivalence: The impacts of methane on climate, ecosystems, and health. Environ Sci Policy. 2022;134:127–36. [DOI]
13. Bera M, Nag PK. Global research trends on climate change-induced heat stress and its impacts on health and productivity of outdoor workers: a systematic review. Theor Appl Climatol. 2026;157:1. [DOI]
14. Kjellstrom T, Freyberg C, Lemke B, Otto M, Briggs D. Estimating population heat exposure and impacts on working people in conjunction with climate change. Int J Biometeorol. 2018;62:291–306. [DOI] [PubMed]
15. Flouris AD, Dinas PC, Ioannou LG, Nybo L, Havenith G, Kenny GP, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. Lancet Planet Health. 2018;2:e521–31. [DOI] [PubMed]
16. Working on a warmer planet: The impact of heat stress on productivity and decent work [Internet]. Geneva: International Labour Organization (ILO); c1996–2026. [cited 2025 Dec 16]. Available from: https://www.ilo.org/publications/major-publications/working-warmer-planet-effect-heat-stress-productivity-and-decent-work
17. Chevance G, Minor K, Vielma C, Campi E, O'Callaghan-Gordo C, Basagaña X, et al. A systematic review of ambient heat and sleep in a warming climate. Sleep Med Rev. 2024;75:101915. [DOI] [PubMed]
18. Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, et al. Hot weather and heat extremes: health risks. Lancet. 2021;398:698–708. [DOI] [PubMed]
19. Vrijheid, M. Understanding environmental exposures in early life for lifelong health. Nat Health. 2026;1:777–80. [DOI]
20. Sulser T, Wiebe KD, Dunston S, Cenacchi N, Nin-Pratt A, Mason-D'Croz D, et al., editors. Climate change and hunger: Estimating costs of adaptation in the agri-food system. International Food Policy Research Institute; 2021.
21. Healy JP, Castro E, Danesh Yazdi M, Rice MB, Chang H, Steenland K, et al. Heat waves and annual mortality among older adults (aged ≥65 years) in the USA. Lancet Planet Health. 2026;10:101432. [DOI] [PubMed] [PMC]
22. van Daalen KR, Tonne C, Semenza JC, Rocklöv J, Markandya A, Dasandi N, et al. The 2024 Europe report of the Lancet Countdown on health and climate change: unprecedented warming demands unprecedented action. Lancet Public Health. 2024;9:e495–522. [DOI] [PubMed] [PMC]
23. van Daalen K, Jung L, Dhatt R, Phelan AL. Climate change and gender-based health disparities. Lancet Planet Health. 2020;4:e44–5. [DOI] [PubMed]
24. Karlsen TH, Sheron N, Zelber-Sagi S, Carrieri P, Dusheiko G, Bugianesi E, et al. The EASL-Lancet Liver Commission: protecting the next generation of Europeans against liver disease complications and premature mortality. Lancet. 2022;399:61–116. [DOI] [PubMed]
25. World report on the health of refugees and migrants: summary [Internet]. WHO; c2026. [cited 2025 Dec 16]. Available from: https://www.who.int/publications/i/item/9789240054462
26. Kälin W, Weerasinghe S. Environmental migrants and global governance: facts, policies and practices. In: IOM, editor. Migration Research Leaders' Syndicate. Geneva: International Organization for Migration; 2017. pp. 37–47.
27. Myran DT, Morton R, Biggs BA, Veldhuijzen I, Castelli F, Tran A, et al. The Effectiveness and Cost-Effectiveness of Screening for and Vaccination Against Hepatitis B Virus among Migrants in the EU/EEA: A Systematic Review. Int J Environ Res Public Health. 2018;15:1898. [DOI] [PubMed] [PMC]

28. Ballester J, Quijal-Zamorano M, Méndez Turrubiates RF, Pegenaute F, Herrmann FR, Robine JM, et al. Heat-related mortality in Europe during the summer of 2022. Nat Med. 2023;29:1857–66. [DOI] [PubMed] [PMC]
29. Willow Master Development Plan Supplemental Environmental Impact Statement [Internet]. [cited 2026 May 16]. Available from: https://eplanning.blm.gov/Project-Home/?id=f07b7ab1-a7f2-f011-8407-001dd80b1f5f
30. Asrani SK, Devarbhavi H, Eaton J, Kamath PS. Burden of liver diseases in the world. J Hepatol. 2019; 70:151–71. [DOI] [PubMed]
31. Devarbhavi H, Asrani SK, Arab JP, Nartey YA, Pose E, Kamath PS. Global burden of liver disease: 2023 update. J Hepatol. 2023;79:516–37. [DOI] [PubMed]
32. Orru H, Ebi KL, Forsberg B. The Interplay of Climate Change and Air Pollution on Health. Curr Environ Health Rep. 2017;4:504–13. [DOI] [PubMed] [PMC]
33. Xu J, Wang Q, Anikeeva O, Zhu P, Bi P, Huang C. Effects of extreme heat on physiology, morbidity, and mortality under climate change: mechanisms and clinical implications. BMJ. 2025;391:e084675. [DOI] [PubMed]
34. Mora C, Counsell CWW, Bielecki CR, Louis LV. Twenty-Seven Ways a Heat Wave Can Kill You: Deadly Heat in the Era of Climate Change. Circ Cardiovasc Qual Outcomes. 2017;10:e004233. [DOI] [PubMed]
35. Vergunst F, Berry HL, Minor K, Chadi N. Climate Change and Substance-Use Behaviors: A Risk-Pathways Framework. Perspect Psychol Sci. 2023;18:936–54. [DOI] [PubMed] [PMC]
36. Iaccarino J, Mignini I, Maresca R, Giansanti G, Esposto G, Borriello R, et al. The Impact of Air Pollution on the Lung-Gut-Liver Axis: Oxidative Stress and Its Role in Liver Disease. Antioxidants (Basel). 2025;14:1148. [DOI] [PubMed] [PMC]
37. Malig BJ, Wu XM, Guirguis K, Gershunov A, Basu R. Associations between ambient temperature and hepatobiliary and renal hospitalizations in California, 1999 to 2009. Environ Res. 2019;177:108566. [DOI] [PubMed]
38. Melaram R. Environmental Risk Factors Implicated in Liver Disease: A Mini-Review. Front Public Health. 2021;9:683719. [DOI] [PubMed] [PMC]
39. Law AV, Sakharkar P, Zargarzadeh A, Tai BW, Hess K, Hata M, et al. Taking stock of medication wastage: Unused medications in US households. Res Social Adm Pharm. 2015;11:571–8. [DOI] [PubMed]
40. Or Z, Seppänen AV. The role of the health sector in tackling climate change: A narrative review. Health Policy. 2024;143:105053. [DOI] [PubMed]
41. Bosurgi R. Climate crisis: healthcare is a major contributor, global report finds. BMJ. 2019;366:l5560. [DOI] [PubMed]
42. Lacroute J, Marcantoni J, Petitot S, Weber J, Levy P, Dirrenberger B, et al. The carbon footprint of ambulatory gastrointestinal endoscopy. Endoscopy. 2023;55:918–26. [DOI] [PubMed] [PMC]
43. Janik-Karpinska E, Brancaleoni R, Niemcewicz M, Wojtas W, Foco M, Podogrocki M, et al. Healthcare Waste-A Serious Problem for Global Health. Healthcare (Basel). 2023;11:242. [DOI] [PubMed] [PMC]
44. The CAT thermometer explained [Internet]. Climate Analytics and New Climate Institute.; c2025 [cited 2025 Dec 19]. Available from: https://climateactiontracker.org/global/cat-thermometer/
45. Whitmee S, Green R, Belesova K, Hassan S, Cuevas S, Murage P, et al. Pathways to a healthy net-zero future: report of the Lancet Pathfinder Commission. Lancet. 2024;403:67–110. [DOI] [PubMed]
46. Mora C, McKenzie T, Gaw IM, Dean JM, Hvon Hammerstein H, Knudson TA, et al. Over half of known human pathogenic diseases can be aggravated by climate change. Nat Clim Chang. 2022;12:869–75. [DOI] [PubMed] [PMC]
47. Mills JN, Gage KL, Khan AS. Potential influence of climate change on vector-borne and zoonotic diseases: a review and proposed research plan. Environ Health Perspect. 2010;118:1507–14. [DOI] [PubMed] [PMC]

48. Tambo E, Chen JH, Zhou XN, Khater EI. Outwitting dengue threat and epidemics resurgence in Asia-Pacific countries: strengthening integrated dengue surveillance, monitoring and response systems. Infect Dis Poverty. 2016;5:56. [DOI] [PubMed] [PMC]
49. Lindh E, Argentini C, Remoli ME, Fortuna C, Faggioni G, Benedetti E, et al. The Italian 2017 Outbreak Chikungunya Virus Belongs to an Emerging *Aedes albopictus*-Adapted Virus Cluster Introduced From the Indian Subcontinent. Open Forum Infect Dis. 2018;6:ofy321. [DOI] [PubMed] [PMC]
50. Calba C, Guerbois-Galla M, Franke F, Jeannin C, Auzet-Caillaud M, Grard G, et al. Preliminary report of an autochthonous chikungunya outbreak in France, July to September 2017. Euro Surveill. 2017;22:17-00647. [DOI] [PubMed] [PMC]
51. Paaijmans KP, Blanford S, Bell AS, Blanford JI, Read AF, Thomas MB. Influence of climate on malaria transmission depends on daily temperature variation. Proc Natl Acad Sci U S A. 2010;107:15135–9. [DOI] [PubMed] [PMC]
52. Gao L, Zhang Y, Ding G, Liu Q, Wang C, Jiang B. Projections of hepatitis A virus infection associated with flood events by 2020 and 2030 in Anhui Province, China. Int J Biometeorol. 2016;60:1873–84. [DOI] [PubMed]
53. Dengue-global situation [Internet]. WHO; c2026 [cited 2024 Dec 21]. Available from: https://www.who.int/emergencies/disease-outbreak-news/item/2023-DON498
54. Stanaway JD, Shepard DS, Undurraga EA, Halasa YA, Coffeng LE, Brady OJ, et al. The global burden of dengue: an analysis from the Global Burden of Disease Study 2013. Lancet Infect Dis. 2016;16:712–23. [DOI] [PubMed] [PMC]
55. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. The global distribution and burden of dengue. Nature. 2013;496:504–7. [DOI] [PubMed] [PMC]
56. Clarke J, Lim A, Gupte P, Pigott DM, van Panhuis WG, Brady OJ. A global dataset of publicly available dengue case count data. Sci Data. 2024;11:296. [DOI] [PubMed] [PMC]
57. Rocklöv J, Tozan Y. Climate change and the rising infectiousness of dengue. Emerg Top Life Sci. 2019;3:133–42. [DOI] [PubMed] [PMC]
58. Kraemer MUG, Reiner RC Jr, Brady OJ, Messina JP, Gilbert M, Pigott DM, et al. Past and future spread of the arbovirus vectors Aedes aegypti and Aedes albopictus. Nat Microbiol. 2019;4:854–63. [DOI] [PubMed] [PMC]
59. Data and Statistics on Dengue in the United States [Internet]. [cited 2025 Dec 22]. Available from: https://www.cdc.gov/dengue/data-research/facts-stats/index.html
60. Brown JJ, Pascual M, Wimberly MC, Johnson LR, Murdock CC. Humidity—The overlooked variable in the thermal biology of mosquito-borne disease. Ecol Lett. 2023;26:1029–49. [DOI] [PubMed] [PMC]
61. Siraj AS, Santos-Vega M, Bouma MJ, Yadeta D, Ruiz Carrascal D, Pascual M. Altitudinal changes in malaria incidence in highlands of Ethiopia and Colombia. Science. 2014;343:1154–8. [DOI] [PubMed]
62. Lyon B, Dinku T, Raman A, Thomson MC. Temperature suitability for malaria climbing the Ethiopian Highlands. Environ Res Lett. 2017;12:064015. [DOI]
63. Grover-Kopec EK, Blumenthal MB, Ceccato P, Dinku T, Omumbo JA, Connor SJ. Web-based climate information resources for malaria control in Africa. Malar J. 2006;5:38. [DOI] [PubMed] [PMC]
64. Heidecke J, Lavarello Schettini A, Rocklöv J. West Nile virus eco-epidemiology and climate change. PLOS Clim. 2023;2:e0000129. [DOI]
65. Erazo D, Grant L, Ghisbain G, Marini G, Colón-González FJ, Wint W, et al. Contribution of climate change to the spatial expansion of West Nile virus in Europe. Nat Commun. 2024;15:1196. [DOI] [PubMed] [PMC]
66. Baker RE, Mahmud AS, Miller IF, Rajeev M, Rasambainarivo F, Rice BL, et al. Infectious disease in an era of global change. Nat Rev Microbiol. 2022;20:193–205. [DOI] [PubMed] [PMC]
67. Walker RJ, Kingpriest PT, Gong J, Naisanga M, Ashraf MN, Roberti J, et al. Global perspectives on infectious diseases at risk of escalation and their drivers. Sci Rep. 2025;15:38630. [DOI] [PubMed] [PMC]

68. Dupke S, Buchholz U, Fastner J, Förster C, Frank C, Lewin A, et al. Impact of climate change on waterborne infections and intoxications. J Health Monit. 2023;8:62–77. [DOI] [PubMed] [PMC]
69. Froelich BA, Daines DA. In hot water: effects of climate change on Vibrio-human interactions. Environ Microbiol. 2020;22:4101–11. [DOI] [PubMed]
70. Archer EJ, Baker-Austin C, Osborn TJ, Jones NR, Martínez-Urtaza J, Trinanes J, et al. Climate warming and increasing Vibrio vulnificus infections in North America. Sci Rep. 2023;13:3893. [DOI] [PubMed] [PMC]
71. Su X, Zheng L, Zhang H, Shen T, Liu Y, Hu X. Secular Trends of Acute Viral Hepatitis Incidence and Mortality in China, 1990 to 2019 and Its Prediction to 2030: The Global Burden of Disease Study 2019. Front Med (Lausanne). 2022;9:842088. [DOI] [PubMed] [PMC]
72. Hepatitis E virus—Republic of South Sudan [Internet]. WHO; c2026 [cited 2025 Nov 19]. Available from: https://www.who.int/emergencies/disease-outbreak-news/item/hepatitis-e-virus-republic-of-south-sudan
73. Modabbernia G, Meshgi B, Kinsley AC. Climatic variations and Fasciola: a review of impacts across the parasite life cycle. Parasitol Res. 2024;123:300. [DOI] [PubMed]
74. Zanaty N, Ibrahim N, Ramadan HK, Ahmad AA, Saad-Hussein A. Significance of climate change in the emergence of human fascioliasis in Upper Egypt. Trop Dis Travel Med Vaccines. 2024;10:24. [DOI] [PubMed] [PMC]
75. Karanasiou A, Moreno N, Moreno T, Viana M, de Leeuw F, Querol X. Health effects from Sahara dust episodes in Europe: literature review and research gaps. Environ Int. 2012;47:107–14. [DOI] [PubMed]
76. Ramalli L, Mulero S, Noël H, Chiappini JD, Vincent J, Barré-Cardi H, et al. Persistence of schistosomal transmission linked to the Cavu river in southern Corsica since 2013. Euro Surveill. 2018;23:18-00017. [DOI] [PubMed] [PMC]
77. Fox NJ, White PCL, McClean CJ, Marion G, Evans A, Hutchings MR. Predicting impacts of climate change on Fasciola hepatica risk. PLoS One. 2011;6:e16126. [DOI] [PubMed] [PMC]
78. Stensgaard AS, Vounatsou P, Sengupta ME, Utzinger J. Schistosomes, snails and climate change: Current trends and future expectations. Acta Trop. 2019;190:257–68. [DOI] [PubMed]
79. McCreesh N, Nikulin G, Booth M. Predicting the effects of climate change on Schistosoma mansoni transmission in eastern Africa. Parasit Vectors. 2015;8:4. [DOI] [PubMed] [PMC]
80. De Leo GA, Stensgaard AS, Sokolow SH, N'Goran EK, Chamberlin AJ, Yang GJ, et al. Schistosomiasis and climate change. BMJ. 2020;371:m4324. [DOI]
81. Yang GJ, Bergquist R. Potential Impact of Climate Change on Schistosomiasis: A Global Assessment Attempt. Trop Med Infect Dis. 2018;3:117. [DOI] [PubMed] [PMC]
82. da Silva BM, Ferreira AF, Silva JAMd, da Amorim RG, Domingues ALC, Pinheiro MCC, et al. High schistosomiasis-related mortality in Northeast Brazil: trends and spatial patterns. Rev Soc Bras Med Trop. 2022;55:e0431. [DOI] [PubMed] [PMC]
83. Scholte RGC, Gosoniu L, Malone JB, Chammartin F, Utzinger J, Vounatsou P. Predictive risk mapping of schistosomiasis in Brazil using Bayesian geostatistical models. Acta Trop. 2014;132:57–63. [DOI] [PubMed]
84. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. Hepatology. 2016;64:73–84. [DOI] [PubMed]
85. Riazi K, Azhari H, Charette JH, Underwood FE, King JA, Afshar EE, et al. The prevalence and incidence of NAFLD worldwide: a systematic review and meta-analysis. Lancet Gastroenterol Hepatol. 2022;7:851–61. [DOI] [PubMed]
86. Swinburn BA, Kraak VI, Allender S, Atkins VJ, Baker PI, Bogard JR, et al. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. Lancet. 2019;393:791–846. [DOI] [PubMed]

87. Wheeler T, von Braun J. Climate change impacts on global food security. Science. 2013;341:508–13. [DOI] [PubMed]
88. Trentinaglia MT, Parolini M, Donzelli F, Olper A. Climate change and obesity: a global analysis. Glob Food Secur. 2021;29:100539. [DOI]
89. Farrell P, Thow AM, Abimbola S, Faruqui N, Negin J. How food insecurity could lead to obesity in LMICs: When not enough is too much: a realist review of how food insecurity could lead to obesity in low- and middle-income countries. Health Promot Int. 2018;33:812–26. [DOI] [PubMed]
90. McLaren DS, Bitar JG, Nassar VH. Protein-calorie malnutrition and the liver. Prog Liver Dis. 1972;4: 527–36. [PubMed]
91. Devi MJ, Malhotra A, Ranjan P, Sabharwal M, Byloppilly G. MASLD in the next generation: metabolic and lifestyle factors shaping the disease in young adults. Int J Health Sci Res. 2025;15:79–92. [DOI]
92. Donnelly MC, Stableforth W, Krag A, Reuben A. The Negative Bidirectional Interaction Between Climate Change and the Prevalence and Care of Liver Disease: A Joint BSG, BASL, EASL, and AASLD Commentary. Gastroenterology. 2022;162:1561–7. [DOI] [PubMed]
93. Shi L, Du X, Liu H, Chen X, Ma Y, Wang R, et al. Update on the adverse effects of microcystins on the liver. Environ Res. 2021;195:110890. [DOI] [PubMed]
94. Wang Y, Gao X, Wang Q, Li Y, Li Q, Xing Y, et al. Nonlinear climate–Liver gradients: Non-optimal temperature and variability increase risk of metabolic dysfunction-associated steatotic liver disease. Glob Transit. 2026;8:259–68. [DOI]
95. Wu Y, Li S, Zhao Q, Wen B, Gasparrini A, Tong S, et al. Global, regional, and national burden of mortality associated with short-term temperature variability from 2000-19: a three-stage modelling study. Lancet Planet Health. 2022;6:e410–21. [DOI] [PubMed] [PMC]
96. Straat ME, Jurado-Fasoli L, Ying Z, Nahon KJ, Janssen LGM, Boon MR, et al. Cold exposure induces dynamic changes in circulating triacylglycerol species, which is dependent on intracellular lipolysis: A randomized cross-over trial. EBioMedicine. 2022;86:104349. [DOI] [PubMed] [PMC]
97. Lei T, Hua H, Du H, Xia J, Xu D, Liu W, et al. Molecular mechanisms of artificial light at night affecting circadian rhythm disturbance. Arch Toxicol. 2024;98:395–408. [DOI] [PubMed]
98. Meléndez-Fernández OH, Liu JA, Nelson RJ. Circadian Rhythms Disrupted by Light at Night and Mistimed Food Intake Alter Hormonal Rhythms and Metabolism. Int J Mol Sci. 2023;24:3392. [DOI] [PubMed] [PMC]
99. Araneda OF, Carbonell T, Tuesta M. Update on the Mechanisms of Pulmonary Inflammation and Oxidative Imbalance Induced by Exercise. Oxid Med Cell Longev. 2016;2016:4868536. [DOI] [PubMed] [PMC]
100. Romanos M, Garcia Cordova JM, Villamarin J, Pazmino Zurita JD, Acosta A. Obesity and Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD): A Literature Review on Pathophysiology and Treatment. Diabetes Obes Metab. 2026;28:19–30. [DOI] [PubMed] [PMC]
101. Liew WP, Mohd-Redzwan S. Mycotoxin: Its Impact on Gut Health and Microbiota. Front Cell Infect Microbiol. 2018;8:60. [DOI] [PubMed] [PMC]
102. Gan T, Bambrick H, Ebi KL, Hu W. Does global warming increase the risk of liver cancer in Australia? Perspectives based on spatial variability. Sci Total Environ. 2023;859:160412. [DOI] [PubMed]
103. Horvatits T, Tamminga M, Liu B, Sebode M, Carambia A, Fischer L, et al. Microplastics detected in cirrhotic liver tissue. EBioMedicine. 2022;82:104147. [DOI] [PubMed] [PMC]
104. Pedersen M, Andersen ZJ, Stafoggia M, Weinmayr G, Galassi C, Sørensen M, et al. Ambient air pollution and primary liver cancer incidence in four European cohorts within the ESCAPE project. Environ Res. 2017;154:226–33. [DOI] [PubMed]
105. Lin S, Han L, Li D, Wang T, Wu Z, Zhang H, et al. The Association between Meteorological Factors and the Prevalence of Acute-on-chronic Liver Failure: A Population-based Study, 2007-2016. J Clin Transl Hepatol. 2019;7:341–5. [DOI] [PubMed] [PMC]

106. McMillin M. Can Weather Influence the Prevalence of Acute-on-chronic Liver Failure? J Clin Transl Hepatol. 2019;7:285–6. [DOI] [PubMed] [PMC]
107. Žūkienė R, Naučienė Z, Šilkūnienė G, Vanagas T, Gulbinas A, Zimkus A, et al. Contribution of mitochondria to injury of hepatocytes and liver tissue by hyperthermia. Medicina (Kaunas). 2017;53: 40–9. [DOI] [PubMed]
108. Fadhlillah F, Turner J, Reddy U. Therapeutic hypothermia and acute brain injury. Anaest Intens Care M. 2022;23:760–3. [DOI]
109. Fani Marvasti F, Stafford RS. From sick care to health care—reengineering prevention into the U.S. system. N Engl J Med. 2012;367:889–91. [DOI] [PubMed] [PMC]
110. The 90% Prevention Rule: Simple Steps to Protect Your Liver Health [Internet]. London: Leaders in Liver Health; c2025 [cited 2026 Mar 7]. Available from: https://www.leadersinliverhealth.com/liver-disease-prevention-90-percent-preventable/
111. Wyper GMA, Mackay DF, Fraser C, Lewsey J, Robinson M, Beeston C, et al. Evaluating the impact of alcohol minimum unit pricing on deaths and hospitalisations in Scotland: a controlled interrupted time series study. Lancet. 2023;401:1361–70. [DOI] [PubMed] [PMC]
112. Hudson B, Round J, Georgeson B, Pring A, Forbes K, McCune CA, et al. Cirrhosis with ascites in the last year of life: a nationwide analysis of factors shaping costs, health-care use, and place of death in England. Lancet Gastroenterol Hepatol. 2018;3:95–103. [DOI] [PubMed]
113. Springmann M, Wiebe K, Mason-D'Croz D, Sulser TB, Rayner M, Scarborough P. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. Lancet Planet Health. 2018;2:e451–61. [DOI] [PubMed] [PMC]
114. Mazidi M, Kengne AP. Higher adherence to plant-based diets are associated with lower likelihood of fatty liver. Clin Nutr. 2019;38:1672–7. [DOI] [PubMed]
115. Sung KC, Ryu S, Lee JY, Kim JY, Wild SH, Byrne CD. Effect of exercise on the development of new fatty liver and the resolution of existing fatty liver. J Hepatol. 2016;65:791–7. [DOI] [PubMed]
116. Brand C, Götschi T, Dons E, Gerike R, Anaya-Boig E, Avila-Palencia I, et al. The climate change mitigation impacts of active travel: evidence from a longitudinal panel study in seven European cities. Glob Environ Chang. 2021;67:102224. [DOI]
117. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet. 2019;393:447–92. [DOI] [PubMed]
118. Greening the OR [Internet]. Practice Greenhealth; c2025 [cited 2025 Dec 19]. Available from: https://practicegreenhealth.org/topics/greening-operating-room/greening-or
119. MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. Lancet Planet Health. 2017;1:e381–8. [DOI] [PubMed]
120. Baddeley R, Aabakken L, Veitch A, Hayee B. Green Endoscopy: Counting the Carbon Cost of Our Practice. Gastroenterology. 2022;162:1556–60. [DOI] [PubMed]
121. Vaccari M, Tudor T, Perteghella A. Costs associated with the management of waste from healthcare facilities: An analysis at national and site level. Waste Manag Res. 2018;36:39–47. [DOI] [PubMed]
122. Namburar S, von Renteln D, Damianos J, Bradish L, Barrett J, Aguilera-Fish A, et al. Estimating the environmental impact of disposable endoscopic equipment and endoscopes. Gut. 2022;71:1326–31. [DOI] [PubMed]
123. Sheffield KM, Han Y, Kuo YF, Riall TS, Goodwin JS. Potentially inappropriate screening colonoscopy in Medicare patients: variation by physician and geographic region. JAMA Intern Med. 2013;173: 542–50. [DOI] [PubMed] [PMC]
124. Meshram KK. The circular economy, 5R framework, and green organic practices: pillars of sustainable development and zero-waste living. Discov Environ. 2024;2:147. [DOI]

125. Sharif K, de Santiago ER, David P, Afek A, Gralnek IM, Ben-Horin S, et al. Ecogastroenterology: cultivating sustainable clinical excellence in an environmentally conscious landscape. Lancet Gastroenterol Hepatol. 2024;9:550–63. [DOI] [PubMed]
126. Yong KK, He Y, Cheung HCA, Sriskandarajah R, Jenkins W, Goldin R, et al. Rationalising the use of specimen pots following colorectal polypectomy: a small step towards greener endoscopy. Frontline Gastroenterol. 2022;14:295–9. [DOI] [PubMed] [PMC]
127. Pal P, Mateen MA, Pooja K, Marri UK, Gupta R, Tandan M, et al. Leveraging existing mid-end ultrasound machine for point-of-care intestinal ultrasound in low-resource settings: Prospective, real-world impact on clinical decision-making. Aliment Pharmacol Ther. 2024;60:633–47. [DOI] [PubMed]
128. de Franchis R, Bosch J, Garcia-Tsao G, Reiberger T, Ripoll C, Faculty BV, et al. Baveno VII—Renewing consensus in portal hypertension. J Hepatol. 2022;76:959–74. [DOI] [PubMed] [PMC]
129. Eckelman MJ, Huang K, Lagasse R, Senay E, Dubrow R, Sherman JD. Health Care Pollution And Public Health Damage In The United States: An Update. Health Aff (Millwood). 2020;39:2071–9. [DOI] [PubMed]
130. Shrank WH, Rogstad TL, Parekh N. Waste in the US Health Care System: Estimated Costs and Potential for Savings. JAMA. 2019;322:1501–9. [DOI] [PubMed]
131. Hollander JE, Carr BG. Virtually Perfect? Telemedicine for Covid-19. N Engl J Med. 2020;382: 1679–81. [DOI] [PubMed]
132. Pradeep A, Barker F, Ramos K, Littlejohn W, Tavabie OD, Nicholson C, et al. Virtual liver transplant assessment: a novel pathway that is likely safe, effective and optimises access to transplantation. Frontline Gastroenterol. 2021;13:360–2. [DOI] [PubMed] [PMC]
133. Eqbal A, Wickremeratne T, Turner S, Higgins SE, Sloss A, Mitchell J, et al. One-stop shop for variceal surveillance: integration of unsedated ultrathin endoscopy into the routine clinic visit. Frontline Gastroenterol. 2021;12:545–9. [DOI] [PubMed] [PMC]
134. Hartl L, Semmler G, Hofer BS, Schirwani N, Jachs M, Simbrunner B, et al. COVID-19-Related Downscaling of In-Hospital Liver Care Decreased Patient Satisfaction and Increased Liver-Related Mortality. Hepatol Commun. 2021;5:1660–75. [DOI] [PubMed] [PMC]