

# Global Warming and Endocrinology: The Hyderabad Declaration of the South Asian Federation of Endocrine Societies

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## Abstract

Global warming and endocrine disorders are intertwined issues posing significant challenges. Greenhouse gases emanating from human activities drive global warming, leading to temperature rise and altered weather patterns. South Asia has experienced a noticeable temperature surge over the past century. The sizable population residing in the region heightens the susceptibility to the impact of global warming. In addition to affecting agriculture, water resources, and livelihood, environmental changes interfere with endocrine functioning. Resulting lifestyle changes increase the risk of metabolic and endocrine disorders. Individuals with diabetes face heightened vulnerability to extreme weather due to impaired thermoregulation. A high ambient temperature predisposes to heat-related illnesses, infertility, and nephropathy. Additionally, essential endocrine drugs and medical devices are susceptible to temperature fluctuations. The South Asian Federation of Endocrine Societies (SAFES) calls for collaboration among stakeholders to combat climate change and promote healthy living. Comprehensive approaches, including the establishment of sustainable food systems, promotion of physical activity, and raising awareness about environmental impacts, are imperative. SAFES recommends strategies such as prioritizing plant-based diets, reducing meat consumption, optimizing medical device usage, and enhancing accessibility to endocrine care. Raising awareness and educating caregivers and people living with diabetes on necessary precautions during extreme weather conditions are paramount. The heat sensitivity of insulin, blood glucose monitoring devices, and insulin pumps necessitates proper storage and consideration of environmental conditions for optimal efficacy. The inter-connectedness of global warming and endocrine disorders underscores the necessity of international collaboration guided by national endocrine societies. SAFES urges all stakeholders to actively implement sustainable practices to improve endocrine health in the face of climate change.

**Keywords:** Diabetes, global warming, greenhouse gases, heat-related illness, obesity, South Asia

## INTRODUCTION

Global warming and endocrine disorders are inter-connected in many ways and pose significant challenges to the environment and well-being. While seemingly disparate, these problems

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share common roots in the modern lifestyle and ecological changes. Greenhouse gases intensify global warming, leading to higher temperatures and disrupted weather patterns, affecting ecosystems, agriculture, and human living conditions.<sup>[1]</sup> South Asia has experienced a noticeable increase in average temperatures over the past few decades. Rising temperatures contribute to heatwaves, affecting agriculture, water resources, and human health.<sup>[2]</sup>

This environmental transformation directly and indirectly impacts endocrine function, contributing to heat-related illnesses (HRIs), reproductive disorders, renal stones, and heat-stress nephropathy.<sup>[3-6]</sup> Temperature shifts and weather changes discourage outdoor activities and reduce physical activity, predisposing to obesity.<sup>[7]</sup> Individuals with diabetes and endocrine disorders are more susceptible to extreme heat events.<sup>[8-10]</sup> Additionally, medical devices, drug delivery systems, and essential endocrine drugs are vulnerable to temperature fluctuations, compromising their effectiveness.<sup>[11-13]</sup> Global warming influences endocrine health and healthcare in various ways. On behalf of the South Asian Federation of Endocrine Societies (SAFES), we have addressed these issues in the Hyderabad Declaration.

## GREENHOUSE EFFECT AND GLOBAL WARMING

Global warming is a phenomenon primarily driven by the greenhouse effect. Certain gases in the earth's atmosphere increase the temperature by trapping heat from the sun. These greenhouse gases include carbon dioxide, methane, and nitrous oxide, as well as fluorinated gases such as hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride.<sup>[14]</sup>

When solar radiation reaches the earth, some of it is absorbed by the surface to warm the planet. The earth then radiates the heat back into the space. Greenhouse gases absorb and re-emit some of this infrared radiation, trapping heat and preventing it from escaping entirely. This natural greenhouse effect is crucial for maintaining the temperature conducive to life on earth.<sup>[15]</sup>

However, human activities, such as burning fossil fuels, deforestation, and industrial processes, have significantly increased the concentrations of greenhouse gases. The enhanced greenhouse effect intensifies heat trapping, leading to a rise in temperature. The consequences include climate change, rising sea levels, extreme weather events, and several other environmental adversities, generating problems for mankind.<sup>[16]</sup>

## GLOBAL WARMING IN SOUTH ASIAN CONTEXT: ENDOCRINE PERSPECTIVE

### Recommendation 1

**There is an urgent need to address and mitigate the threat of global warming.**

### Recommendation 2

**It is imperative to raise awareness about global warming and endocrine disorders. Sustainable and sensible lifestyle and healthcare practices must be encouraged.**

## DISCUSSION

The impact of global warming in South Asia is pronounced, with the region experiencing notable environmental changes and challenges. Over the past century, South Asia has witnessed a temperature increase of 0.75°C, and projections indicate a potential additional rise of at least 3.7°C by the end of the century.<sup>[2]</sup> The escalating trend poses serious threats to multiple facets of life in the region, including livelihoods, health, and the economy.

Altered weather patterns, increased frequency of extreme events, and rising sea levels directly affect agriculture, water resources, and human settlements.<sup>[17]</sup> The heightened temperature contributes to health risks, potentially impacting vulnerable populations and straining healthcare systems, especially in resource-limited settings like South Asia.

The South Asian population exhibits an increased predisposition to metabolic diseases. Genetic susceptibility, dietary patterns, and lifestyle choices collectively contribute to its heightened prevalence.<sup>[18]</sup> Extreme weather events disrupt staple crop production, leading to food shortages and shifting eating habits toward energy-dense processed foods. Changes in temperature and weather patterns discourage outdoor activities, fostering sedentary lifestyles and reducing physical activity.<sup>[7]</sup> Decreased physical activity, combined with dietary shifts, exacerbates the risk of metabolic and endocrine disorders in a population already predisposed.

Addressing the interplay between global warming and endocrine disorders requires comprehensive strategies. These may include promoting sustainable food systems, encouraging physical activity, and advocating the impact of lifestyle choices on environmental changes. The SAFES urges all stakeholders to increase awareness and work together to integrate efforts to combat climate change and promote healthy living.

## FOOD AND LIFESTYLE CHOICES TO PREVENT GLOBAL WARMING

### Recommendation 3

**Food choices: Prioritize plant-based diets and reduce meat consumption, particularly red and processed meats, as livestock farming contributes significantly to greenhouse gas emissions. Choosing locally produced and seasonal foods will support regional agriculture and reduce the carbon footprint associated with transportation. Food wasting should be minimized. Composting organic waste to divert it from landfills can reduce the generation of methane, a potent greenhouse gas.**

#### Recommendation 4

**Physical activity and lifestyle: Incorporate regular physical activity into daily routines. Choose walking, cycling, or public transportation over private vehicles to reduce carbon emissions. Conserve energy by using energy-efficient appliances, turning off lights and electronics when not in use, minimizing air conditioners, and maximizing natural lighting and ventilation.**

### DISCUSSION

The climate impact of food is gauged by the intensity of its greenhouse gas emissions, measured in kilograms of “carbon dioxide equivalents” per kilogram of food, per gram of protein, or per calorie. This metric encompasses all greenhouse gases, not just CO<sub>2</sub>. Animal-based foods, particularly red meat, dairy, and farmed shrimp, exhibit the highest greenhouse gas emissions. The production of meat often necessitates extensive grasslands, resulting in deforestation and the release of stored carbon dioxide in forests. Cows and sheep emit methane during digestion. Cattle excreta and the use of chemical fertilizers for cattle feed release nitrous oxide, another potent greenhouse gas. Shifting food systems toward plant-rich diets featuring more plant protein (beans, chickpeas, lentils, nuts, and grains) and lower intake of red meat and saturated fats (butter, milk, cheese, meat, coconut oil, and palm oil) can decrease greenhouse gas emissions.<sup>[19]</sup>

Food wasting should be minimized by planning meals, storing food properly, and repurposing leftovers. Increasing physical activity and using walking and cycling as a means of transport in preference to motorized transport will not only decrease carbon emissions but also help combat metabolic disorders such as diabetes and obesity and enhance overall well-being.

### GREEN ENDOCRINE PRACTICES

#### Recommendation 5

**Availability of endocrine care: The demand for healthcare services in diabetes, obesity, and metabolic disorders has surged. Enhancing the availability of endocrine diagnostic and therapeutic services will not only improve health outcomes but also minimize the need and cost of avoidable transport.**

#### Recommendation 6

**Optimizing medical device usage: Institute efficient and sustainable healthcare practices, such as preferring reusable devices over single-use ones, using recyclable materials, optimizing diagnostic and therapeutic interventions, and ensuring responsible disposal practices.**

### DISCUSSION

Global warming can disrupt the access and maintenance of quality health services, particularly in the context of diabetes and related conditions. In alignment with the World Diabetes Day

2023 theme, “Access to Diabetes Care,” there is a pressing need for accessible, affordable, and quality services.<sup>[20]</sup> The obstacles to bridging the healthcare gap in South Asia are multi-dimensional, with notable concerns related to healthcare infrastructure and the availability of trained professionals, especially in rural areas.<sup>[21]</sup>

Governments and private stakeholders play a pivotal role in allocating resources, developing policies, and establishing healthcare infrastructure that reaches the remotest areas. Investing in training programs to ensure an adequate number of medical and paramedical professionals is essential to meet the growing healthcare demands. Appropriate handling demands collaborative efforts and a commitment to build a robust and inclusive healthcare system. A resilient and adaptive medical care facility can be built by resolving healthcare infrastructure challenges, promoting education, and fostering community engagement.<sup>[22]</sup>

Implementing sustainable practices in the usage of medical devices will decrease the healthcare sector’s ecological footprint. To minimize the environmental impact of diabetes management, there is a need for innovations that prioritize sustainability in diabetes devices. Positive strides are being made by several manufacturers who are adopting eco-friendly practices. Moving toward reducing plastic packaging and instituting recycling programs to decrease landfill waste are steps in that direction. Eco-friendly manufacturing, increased energy efficiency, waste reduction, and responsible disposal are pivotal in aligning healthcare practices with global sustainability goals.<sup>[23]</sup> Kalra *et al.*,<sup>[24]</sup> in a prior SAFES editorial, advocated green diabetology to prevent diabetes waste from harming the environment.

### DIABETES CARE IN THE CONTEXT OF CLIMATE CHANGE

#### Recommendation 7

**Predisposition to heat-related illness: Individuals with diabetes are vulnerable to extreme weather changes due to impaired thermoregulation. They require vigilant monitoring to detect complications related to heat exposure. Raising public awareness on necessary precautions will minimize the risk of heat-related illnesses.**

#### Recommendation 8

**Increased emergency admission and mortality: Extreme heat events increase emergency department admissions and mortality in people with diabetes, particularly among the elderly, obese, those with chronic kidney disease, cardio-respiratory disorders, and frailty. Careful supervision and a low threshold for intervention are essential. Monitoring for signs of dehydration and closely tracking glycemic parameters, electrolytes, and kidney function are prudent in hot weather.**

### DISCUSSION

Systematic reviews have reported increased admission to emergency departments and mortality after exposure to severe

heat waves.<sup>[8–10]</sup> The mortality risk increased by 18% and morbidity by 10%. Impaired sweating and thermoregulation from autonomic neuropathy predispose to HRI in diabetes.<sup>[25]</sup>

The spectrum of HRIs can range from mild to very severe. The milder forms include heat rash, heat edema, heat cramps, and heat syncope and are treatable by simple measures like removal from the heat source, passive cooling, and supportive management.<sup>[26,27]</sup> The more severe forms are heat exhaustion and heat stroke. Heat exhaustion manifests as mild to moderate symptoms such as fatigue, weakness, nausea, headache, dizziness, and thirst. Appearance of neurological symptoms and core body temperature > 40°C are hallmarks of the more severe heat stroke and can be fatal if untreated.<sup>[28]</sup>

Exertional heat stroke occurs primarily in healthy persons who exceed thermoregulatory boundaries from performing strenuous physical activities. The classic variety occurs in susceptible individuals, including those with diabetes from environmental heat exposure.<sup>[26,28]</sup> Obesity, often coexisting with diabetes, also increases the vulnerability to heat exhaustion and stroke.<sup>[29]</sup> Clinicians in South Asia should be aware of the spectrum of HRI.

Prolonged and repeated exposure to heat has been associated with the development of chronic kidney disease (CKD) in Sri Lanka, India, and Central America.<sup>[30,31]</sup> Dehydration, sub-clinical rhabdomyolysis, hyperosmolarity, and hyperthermia are the possible underlying pathophysiologic mechanisms. Trends toward kidney stone disease and renal colic in warmer months have been observed.<sup>[32]</sup> Dehydration and stones can increase the risk of urinary tract infection.<sup>[5]</sup> Diabetes itself increases the risk of renal complications, and maintaining adequate hydration during extreme heat events can be protective. When the ambient temperature is high, caution is warranted in individuals receiving sodium-glucose cotransporter-2 (SGLT2) inhibitors and diuretics.<sup>[33]</sup>

## GLOBAL WARMING AND REPRODUCTIVE DISORDERS

### Recommendation 9

**Male fertility: Global warming and episodes of heat stress, occupational exposure, and lifestyle factors can elevate the scrotal temperature, adversely affecting semen quality. Strategies to mitigate heat exposure should be considered in males with sub-fertility.**

### Recommendation 10

**Female reproductive disorders: Elevated temperatures and exposure to extreme heat events have been linked to adverse pregnancy outcomes, including pre-maturity, low birth weight, stillbirth, and congenital anomalies. Avoiding extreme heat exposure during pregnancy is recommended.**

## DISCUSSION

The relationship between global warming and reproductive disorders is complex, involving both direct impact on

reproductive physiology and indirect effects through changes in food security, water availability, and disease patterns.

### Male fertility

Global warming and episodes of heat stress, occupational exposure, and lifestyle factors can be responsible for increasing scrotal temperature. A high temperature decreases semen volume, sperm count, sperm concentration, and motility and affects sperm morphology.<sup>[34]</sup> The optimal scrotal temperature for spermatogenesis is 2 to 4°C lower than the body temperature. Each 1°C rise in testicular temperature decreases spermatogenesis by 14%. High temperature reduces sperm motility and induces apoptosis by affecting mitochondrial activity and ATP synthesis.<sup>[35]</sup>

### Female reproductive disorders

The error correction model analyzing the fertility rate of Bangladesh from 1966 to 2015 showed that maximum temperature has a direct as well as indirect negative effect via crop production on the total fertility rate.<sup>[36]</sup> Increased temperature has been associated with pre-maturity, low birth weight, stillbirth, and congenital anomalies.<sup>[37]</sup> Global warming may accelerate the onset of menarche.<sup>[38]</sup>

## ENDOCRINE DISORDERS OR CONDITIONS EXACERBATED BY HEAT

### Recommendation 11

**Heat susceptible conditions: Caution is advised for individuals with thyrotoxicosis, adrenal insufficiency, and diabetes insipidus in hot weather. Heat intolerance, prevalent in thyrotoxicosis, worsens in summer. Symptoms of menopausal hot flashes and hypothalamic heat regulatory disorders may mimic or overlap with those of heat intolerance.**

### Recommendation 12

**Iatrogenic heat intolerance: Rational use of anti-histamines, anti-cholinergics, tricyclic anti-depressants, and anti-psychotics should be encouraged in endocrine practice.**

## DISCUSSION

Heat intolerance is a classic symptom of thyrotoxicosis, with worsening experienced during summer.<sup>[39]</sup> Other endocrine disorders can be affected by increased temperature. Reports suggest that a seasonal variation in cortisol production may exist.<sup>[40]</sup> There may be a need to up-titrate glucocorticoid replacement in adrenal insufficiency if the ambient temperature is high, especially in the presence of signs of heat stress. Of note, unlike Western countries, the usual causes of primary adrenal insufficiency in South Asian nations are tuberculosis and endemic fungal disease.<sup>[41]</sup>

Individuals with diabetes insipidus may be prone to dehydration in a warm atmosphere if access to fluid intake is limited.

Menopausal hot flashes also increase in severity and frequency in warmer months.<sup>[42]</sup> Temperature regulatory disorders induced by hypothalamic damage may also worsen.<sup>[43]</sup> While endocrinologists practicing in South Asia are aware of these fluctuations and alter their practice accordingly, SAFES can work to generate systematic evidence in its support.

Certain medications predispose to heat intolerance by reducing heat loss or increasing endogenous heat production and should be used with caution. Several drugs have been implicated, including amphetamines, diuretics, cocaine, anti-psychotics, metoclopramide, selective serotonin reuptake inhibitors, tricyclic anti-depressants, and anti-histamines.<sup>[44]</sup>

## TEMPERATURE SENSITIVITY OF ENDOCRINE DRUGS

### Recommendation 13

**Insulin:** Individuals with diabetes administering insulin should receive advice regarding insulin stability and potential altered absorption in elevated temperature. Additionally, the impact of heat on the shelf life of other diabetes-related medications should be considered.

### Recommendation 14

**Drugs showing temperature sensitivity:** Endocrine drugs requiring refrigeration include, but are not limited to, GLP-1 analogs, teriparatide, desmopressin, calcitonin, growth hormone, and glucagon. Levothyroxine, which is sensitive to light and moisture, should be stored in an environment with low relative humidity at temperatures below 25°C. The absorption of topical estrogen and testosterone preparations may be altered in extreme heat. Caution should be exerted when these drugs are used at high ambient temperature.

## DISCUSSION

Elevated temperature can lead to changes in the structure and stability of insulin, potentially impacting absorption and effectiveness. Diabetes healthcare providers should advise on proper storage, transportation, and usage of insulin to maintain its stability and efficacy, especially in warm atmosphere.<sup>[45]</sup> Most insulin manufacturers recommend maintaining the temperature of the insulin pen or vial below 25–30°C. Manufacturers typically provide storage and distribution recommendations for refrigeration between 2 and 8°C.<sup>[45]</sup> Recent studies re-assure that insulin is stable even if the temperature fluctuates between 25 and 37°C on a short term.<sup>[46]</sup> Individuals administering insulin should be aware of the potential hazards in high-temperature environments. Higher skin temperature is associated with accelerated and enhanced subcutaneous insulin absorption.<sup>[47]</sup>

Several endocrine drugs are temperature-sensitive and require maintenance of cold chain and storage in refrigeration to retain efficacy.<sup>[13]</sup> Drugs that are used topically or transdermally, such as estrogen and testosterone preparations, demonstrate faster

absorption at higher temperatures due to increased cutaneous blood flow.<sup>[48]</sup>

## TEMPERATURE SENSITIVITY OF MEDICAL DEVICES

### Recommendation 15

**Glucometer and continuous glucose monitoring devices:** Brief exposure to high temperature and humidity can impact glucose test strip accuracy. Inconsistencies should prompt lab confirmation. Manufacturers advise storing strips below 30°C. Increased awareness about temperature-related reading variability is imperative. Elevated temperature and humidity can loosen continuous glucose monitor sensor adhesives, affecting data transmission. Manufacturers recommend temperatures below 45°C for accurate readings. In regions with higher temperatures, such as summer months in many South Asian countries, alternative methods may be preferable.

### Recommendation 16

**Insulin pumps:** High temperature increases skin blood flow and results in more rapid insulin absorption. The risk of pump occlusion also rises. Automated insulin-dosing systems are vulnerable to systematic errors in glucose measurement or insulin delivery. These factors should be taken into consideration if there is ongoing heat exposure.

## DISCUSSION

The recommended temperature for operating a continuous glucose monitoring system (CGMS) is below 45°C.<sup>[11]</sup> In extreme heat beyond this threshold, errors may occur. It is important to assess whether heat waves impact the function of insulin pumps. High temperature can lead to an increased risk of occlusions in the infusion set. Using shorter infusion sets may be helpful in such circumstances. When insulin is exposed to a higher temperature, the risk of air bubble formation increases, potentially impacting pump function, especially when the insulin is used directly after refrigeration.<sup>[11,49]</sup>

## ENVIRONMENTAL POLLUTION AND ENDOCRINE DISORDERS

### Recommendation 17

**Endocrine disrupting chemicals:** The processes contributing to global warming also lead to the release and persistence of endocrine-disrupting chemicals in the environment. Tackling the intertwined challenge requires coordinated efforts at the local, national, and international levels. Increased awareness and further research on the impact of climate change and endocrine disrupting chemicals on human health are urgently required.

### Recommendation 18

**Air pollution-induced metabolic disorders:** Temperature inversions and alterations in weather patterns, induced by global warming, can impact the dispersion of particulate

**matter. Particulate matter air pollution not only affects pulmonary health but also has been linked to the development of metabolic disorders. Additional research is necessary to fully understand and mitigate the metabolic implications of air pollution, which is particularly prevalent in South Asian countries.**

#### Recommendation 19

**Air pollution and vitamin D deficiency: Particulate matter air pollution can filter out ultraviolet B rays required for vitamin D synthesis in the skin. In regions with high air pollution, carefully assess vitamin D status and implement appropriate measures to prevent deficiency.**

## DISCUSSION

Processes such as combustion emissions, industrial waste generation, agricultural practices utilizing pesticides and herbicides, and improper waste disposal contribute to both global warming and environmental contamination. Moreover, extreme weather events associated with global warming can lead to the release of toxic chemicals. Additionally, alterations in temperature and precipitation patterns may impact the distribution and persistence of the toxic substances in the atmosphere.<sup>[7,50]</sup> Many of these substances interfere with the body's endocrine system, disrupting hormone production, metabolism, and signaling, and are labeled as endocrine disrupting chemicals (EDCs).<sup>[51]</sup> EDCs can affect the functioning of every endocrine gland, including bone health, and can also have adverse impacts on growth and metabolism.<sup>[52-54]</sup> The detection of EDCs beyond acceptable limits in foods from South Asian countries is a concerning issue.<sup>[55]</sup> SAFES calls for urgent action to identify and address the potentially harmful effects of these contaminants.

Air pollution has been increasingly recognized as a significant environmental factor contributing to the development and exacerbation of metabolic disorders.<sup>[56]</sup> Data from India indicate that exposure to particulate matter with a diameter of less than 2.5 micrometers (PM<sub>2.5</sub>) affects glycemic markers and the incidence of diabetes.<sup>[57]</sup> SAFES calls for further research to understand the mechanisms underlying the association between PM<sub>2.5</sub> exposure and diabetes risk and to develop targeted interventions for at-risk populations.

Air pollution is one of the major determinants of the extent of solar ultraviolet B (UVB) light reaching the earth surface. Consequently, high ambient air pollution reduces the amount of UVB radiation and lowers the cutaneous synthesis of vitamin D.<sup>[58,59]</sup> This underscores the importance of considering environmental factors, such as air quality, when evaluating and addressing vitamin D status in populations, especially in context of South Asian countries.

## SAFES HYDERABAD DECLARATION

At Hyderabad on December 16, 2023 at the SAFES Summit and ESICON, SAFES calls for enhanced attention to all aspects

of global warming and endocrine care. SAFES requests all stakeholders, including policymakers, planners, healthcare providers including paramedical personnel, and the public, to focus on the recommendations in the Hyderabad Declaration. We urge all the national endocrine societies to promote education among the public about the health effects of global warming and also support research on the impact of climate change on the endocrinological health issues. SAFES will endeavor to discuss and deliberate at all platforms to raise awareness about the threat to our health and the planet.

## CONCLUSION

Global warming and endocrine disorders present inter-connected challenges fueled by escalating greenhouse gases from human activities. With its vast population, South Asia faces heightened vulnerability due to a noticeable temperature surge. Environmental changes impact endocrine function, increasing the risk of developing metabolic disorders. SAFES emphasizes the need to enhance the availability of endocrine care in South Asia and raise awareness about the medical challenges arising from global warming. Concurrently, SAFES calls for collaboration to combat climate change by adopting green endocrinology practices. Endocrinologists should deliberate on environmentally friendly lifestyle choices, which can simultaneously improve health. Optimizing the usage of medical resources, including newer devices, and ensuring appropriate disposal practices will reduce the carbon footprint. SAFES calls upon all national societies to raise awareness and promote research on these facets of endocrine health. Additionally, SAFES urges stakeholders to prioritize the recommendations outlined in the Hyderabad Declaration for individual health and global safety.

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