With Hajj coinciding with the hottest season of the year, Saudi researchers are developing techniques to combat heatstrokes

A smart way to beat the heat

KAIMRC researchers develop a system that can regulate body temperature in real time to help treat heatstroke patients.

Heatstroke is a major concern in Saudi Arabia, especially when the pilgrimage coincides with the hottest months in the kingdom, as it does this year. In 1985, for instance, when pilgrimage came in similarly hot conditions, heatstroke killed more than 1,000 people in just a few days.

KAIMRC researchers have developed a multisensor-based system that mimics the thermoregulatory functions of the hypothalamus. It is set to transform the way life-threatening heatstroke is treated.

Heatstroke expert Abderrezak Bouchama has established a research programme to better understand the impact of heat, and develop effective preventative and therapeutic measures against heatstroke. With co-inventor Ali Almuntashri, his team has devised a method that relies on a hypothalamus-like smart control system to optimize temperature regulation in real time. "We anticipate that this invention will set a new standard for cooling therapy," Bouchama says.

The hypothalamus is a part of the brain that acts as the body's thermostat. It continuously monitors and adjusts the core temperature to 37 degrees Celsius according to environmental temperature changes to ensure normal cellular function. This is done through various responses, including regulating sweat and heat production by the muscles to respond to heat or cold.

Failure of the body's regulatory system can increase the risk of heat illnesses, particularly heatstroke. Heatstroke involves a rapid increase in body temperature above 40 degrees Celsius, associated with neurologic alteration such as delirium, convulsions, or coma. Heat can irreversibly damage cells, causing multiple organ failure and ultimately death.

"This is a true medical emergency because if not withdrawn from the heat and cooled rapidly, the victims will die in just a few hours," says Bouchama.

Heatstroke results from strenuous physical exercise or exposure to extremely high temperatures. It is a major public health problem in Saudi Arabia, especially when the annual pilgrimage to Mecca enters the hot cycle. "Immediately after my arrival in this country [more than 30 years ago], I discovered how devastating heatstroke can be," says Bouchama. According to epidemiological predictions based on 2 million pilgrims, several hundred cases of heatstroke could present during the Hajj, of which approximately 50 percent could die every year. This projection could underestimate the actual prevalence of this heat-related morbidity and mortality because under climate change forecasts, temperatures are expected to soar to extreme levels across the Middle East change, Bouchama adds. Heatstroke has also become an important health concern across the world as a result of global warming.

Beating the heat

Existing measures against heatstroke typically involve reducing heat exposure and physical cooling. Specifically, the patients are immersed in cold water, covered with cold packs or ice slush, or sprayed with cold water and continuously fanned to promote heat evaporation. However, rapid cooling can cause adverse effects, such as discomfort, severe shivering, and skin vasoconstraction, which can promote heating instead of the desired effect. Current state-of-the-art cooling devices, such as cooling pads, endovascular catheters, and blankets, rely on materials that accelerate heat transfer, instead of ice or cold water. Yet, these new devices have brought little improvement compared to conventional methods because they have overlooked the complexity of thermoregulatory response mechanisms, Bouchama explains.

Bouchama's system, however, relies on a hypothalamus-like smart system to prevent the adverse effects of cooling associated with actual cooling techniques. The artificial hypothalamus can simultaneously monitor several physiological parameters, such as core and skin temperatures, cutaneous circulation, and muscle activity, using multiple sensors.

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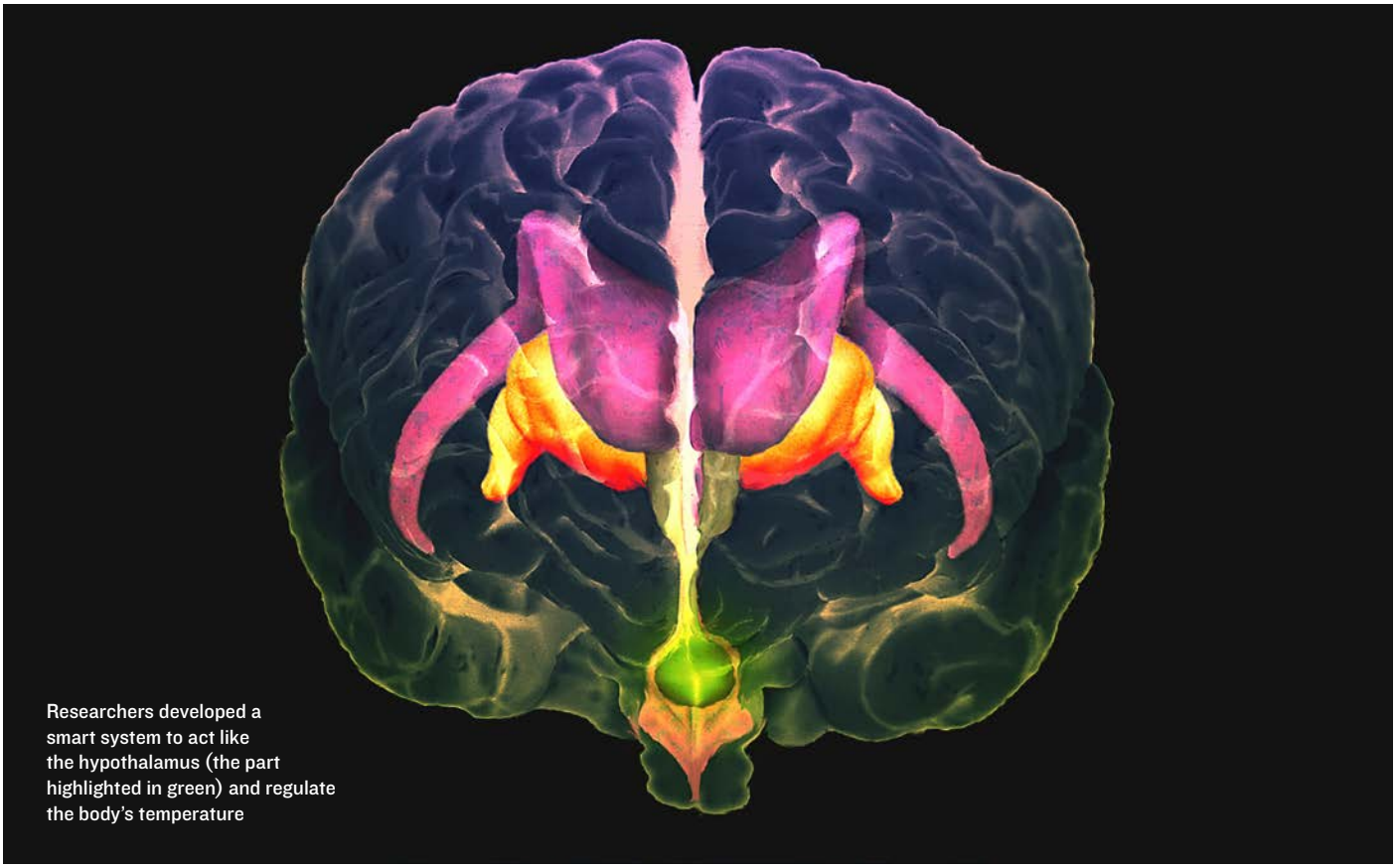

Researchers developed a smart system to act like the hypothalamus (the part highlighted in green) and regulate the body's temperature

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By combining these data, it can react more rapidly than its natural counterpart.

"As soon as these sensors detect a drop in skin temperature, an increase in muscle activity, or a decrease in blood flow before any signal reaches the hypothalamus, the system will stop cooling and activate a warming of the skin until all these data normalize," Bouchama says. In this example, the smart control system helps optimize cooling by bypassing the patient's thermoreceptors and preventing the hypothalamus from triggering adverse effects, such as vasoconstriction and shivering. Once the skin is warm, the system resumes cooling.

The artificial hypothalamus functions via a feedback loop, in which it records the information detected and processed by the sensors, determines whether this information is within a predetermined normal range, and converts this information into so-called fuzzy values if it does not lie within the normal range. Next, it evaluates a set of predetermined rules and combines these rules to generate a precise value, which is transmitted to a set of cooling devices, such as a fan, a cooling blanket, a water circulation device, and an intravascular heat exchange system.

These next-generation cooling techniques equipped with artificial hypothalamus achieve predictable and fast cooling, eliminate shivering, maintain skin blood flow, and reduce the need for sedation or anaesthesia often required to control the adverse effects of current cooling techniques.

The artificial hypothalamus uses a machine-learning algorithm that relies on a network of sensors that include skin blood flow as well as surface and core temperatures and neuromuscular activity measured in real time. This physiology-based cooling system allows the physician to immediately treat a heatstroke patient by programming the device using a temperature profile adapted to the patient's pre-existing health condition, such cardiovascular disease, and modify the program once a final diagnosis is provided.

Bouchama's team, in collaboration with a Saudi company, is currently at the proof-of-concept stage in the development of their artificial hypothalamus. "When this is completed, we will develop a prototype that will be incorporated in any cooling devices," he says.

The anticipated impact in terms of commercialization can be international. At the national level, the impact is immediate because the new cooling bed is a needed component of the public health response to heatstroke, especially as the pilgrimage coincides now with the hottest season. Beyond Saudi Arabia, it can also respond to the need of military, outdoor workers, and athletes who are at risk for heatstroke.

1. Bouchama, A. and Almuntashri, A. Method for regulating body temperature. US Patent 10307287B2, Published June 4, 2019.

2. Bouchama, A. and Almuntashri, A. Artificial hypothalamus for body temperature regulation. US Patent 10188548B2, Published January 29, 2017.