Project title: Modelling human thermoregulatory responses to heat with and without a novel thermal control garment, to help combat health impacts of climate change

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Aim of the Project

To develop a personalised thermophysiological Digital Twin which can be used to predict the health and performance of occupants in thermally challenging environments.

Part 1 will be the development of a next generation thermophysiological model based on a wide range of climatic and personal input parameters, including age, fitness and hydration status. We will also use the model to predict the effectiveness of low cost, sustainable solutions, such as a novel thermal control suit (TCS) which is proposed to maintain body temperature in challenging thermal environments without the need for air conditioning.

Part 2 will involve model validation. Human physiology MSc student projects will be undertaken in the thermal chamber within the Centre for Human and Applied Physiological Sciences at Guy's Campus to assess the thermophysiological response to a wide variety of environmental conditions. The PhD student will use these data to make necessary adjustments to the Digital Twin.

Project Description

Heat waves are increasing in their frequency, intensity, and duration, posing urgent health concerns on an international scale. For example, The Haj pilgrimage in 2024 resulted in over 1,500 heat stroke deaths, while the 2022 heat wave in the UK caused nearly 5,000 extra deaths in those aged over 70 years. To assist in prevention of these mass mortality events in a warming climate, models of human thermoregulation must accurately predict the physiological responses to heat stress before they have taken place.

In order to predict what populations are most at risk, and determine the most effective solutions, mathematical models of human thermoregulation should accurately quantify the physiological response to heat stress, showing the change in variables such as core temperature, heart rate, and fluid balance. The models must also be adjustable based on personal characteristics, such as age, work rate, clothing, and chronic diseases such as heart failure. No models in the literature can meet these criteria, making it difficult to determine the risk associated with climatic heat exposures, and how this varies with the exposure time.

Although thermophysiological models do exist, they are not modifiable based on key personal characteristics which modify the risk of environmental heat exposure. For example, older individuals with chronic diseases are more likely to succumb to environmental heat compared with young health individuals. Yet, there are no models which can predict their physiological responses. Ultimately, available models (such as the Fiala model) provide only a crude estimate of core temperature responses in a given set of conditions, which are only applicable to young healthy adults.

A core component of the work is to develop a next generation mathematical model of human thermoregulation using up to date modelling techniques. The successful candidate will work with world-leading experts in data science and physiological modelling, as well as experts in human physiological responses to extreme environments. The candidate will also test the efficacy of the model against data obtained from real lab experiments with human participants exposed to a wide variety of climates.

Another key component is to use the model to assess the impact of different low cost, sustainable solutions. Examples solutions include 1) a novel thermal suit which cools the person instead of cooling the room (such as with air conditioning), 2) ceiling fans, which increase air flow over the skin allowing more heat to be offloaded to the environment. Being able to predict the effectiveness of these solutions allows health and government agencies to develop a cost-benefit analysis on which solutions should be deployed for a given scenario.

Figure 1: A visualisation of physiological and environmental risk factors throughout the lifecourse (Covostra)