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## A suitable thermal stress index for the elderly in summer tropical climates

Sumavalee Chindapol<sup>a,\*</sup>, John Blair<sup>a</sup>, Paul Osmond<sup>a</sup>, Deo Prasad<sup>b</sup>

<sup>a</sup>Faculty of Built Environment, University of New South Wales, Sydney, 2052, Australia

<sup>b</sup>CRC for Low Carbon Living, University of New South Wales, Sydney, 2052, Australia

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### Abstract

The elderly are particularly vulnerable to heatwaves and this research investigates the degree of thermal stress they experience and identifies a suitable index, using Thailand as the case study location. Several global heat stress indices were evaluated for their ability to predict thermal stress in the tropics: Universal Thermal Climate Index (UTCI), Heat Stress Index (HSI), Tropical Summer Index (TSI), Wet-bulb Globe Temperature Index (WBGT) and Discomfort Index (DI). The UTCI, WBGT and DI group tropical conditions in the zone of greater thermal stress, while the HSI and TSI are clustered in the lower stress categories and are more similar to the thermal sensation vote (TSV) and thermal comfort vote (TCV) definitions. Most indices correlated with the TSV, while only HSI and WBGT show a correlation with TCV. The research concluded that the HSI is the most suitable thermal stress index, although it still does not completely explain tropical heat stress conditions.

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### 1. Introduction

In 2010, Thailand suffered from the hottest summer period in 20 years. For close to three weeks, newspapers were reporting temperatures in excess of 38°C and also a number of heat-related deaths, particularly among the elderly. Although six reported heat-related deaths in three years (2010 - 2013) might not be construed to be significant, heat-related illnesses created 3,963 hospital visits, 20% from the elderly [1]. In 2016, Thailand recorded

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\* Corresponding author. Tel.: +66-631-961-009.

E-mail address: [sumavalee@gmail.com](mailto:sumavalee@gmail.com)

the hottest summer in 65 years with maximum temperature over 40°C for most days of two summer months and temperatures peaking at 44.6°C during the hottest part of one day in a city in Utaradit [2]. Thirty-four heat-related deaths were recorded during these two summer months in 2016. Sources have since commented that most victims were homeless children under 14 years and older people over 65 years or those with chronic diseases [1–3].

These phenomena led this research to question why local people, who should have been acclimatised to a hot-humid climate, died due to the heat and whether many of the deaths could have been prevented. Thus it was decided to investigate the heat stress levels of the elderly during summer to identify their thresholds in both current and future conditions.

### *1.1. Elderly limits*

To date, previous research has attempted to explain the thermal comfort of the elderly in subtropical climates but few studies have covered this group of people in tropical climates. One issue is that the thermal sensitivity of the elderly has deteriorated, proven by numerous studies. The elderly's thermoregulation has diminished with age, leading to failure of sweat control [4–6]; reduction of thermal balance preservation [7, 8]; and a greater reduction of warm compared with cold receptors regarding thermosensitivity [7]. In addition, some of these characteristics can be exacerbated by chronic diseases such as diabetes [9], hypertension [10] and heart problems [11]. These symptoms lead to less accurate thermal sensation [12] and can lead to significantly different degrees of thermal consciousness expressed by the old and the young [13].

### *1.2. Heat stress in Thailand*

Thailand defines a heatwave as the maximum temperature constantly exceeding 40°C for over three days [14]. Heatwaves have not often occurred in Thailand while heat stress is more common. Heat stress is a stage when the body cannot maintain normal thermoregulation, normally by sweating, from excessive heat gain. Generally, heatwave is more likely to happen in two ways: first, it occurs when average maximum and minimum temperatures exceed those of the past three days. Second, it happens when average temperatures exceed those of the past 30 days [15]. From 2010 – 2015, Thailand has experienced heat stress risk every summer [16]. The simulation system for heat stress investigation using the Heat Index (HI) found that Bangkok experienced 49% of the year with 'moderate' heat stress in 2014, the highest proportion of all cities in Thailand [17].

Researchers have paid little attention to heat stress in hot-humid climates. However, recent research has reported heat stress in peninsular Malaysia in more extreme conditions when the UTCI reflected 51.2°C, a unit which combines temperature, humidity and water vapour pressure [18]. In Thailand, a few studies have investigated the effects of heat on occupational environments and found that Thai workers produced 25-30% faster heart rates in the heat than western workers at the same level of oxygen consumption [19–21]. Two recent studies are convinced that heat-related deaths and illness have increased among the Thai people in 1999 - 2008, in particular those who are elderly [22, 23].

## **2. Methods**

### *2.1. Survey*

This research focuses on the heat stress of the elderly in summer in hot-humid Thailand, using Chiangmai as the study site since it is one of the extreme cases of heat exposure during summer. The participants were aged 60 years old and over. The participating elderly were low income residents in four retirement homes in Chiangmai, three urban homes and one rural home. The main survey was conducted during the day from 9 am to 6 pm in semi-outdoor spaces (veranda, pavilion) associated with the retirement homes. Total numbers of the senior participants in the main survey in April to May 2015 translated into 135 datasets. Four physical environment parameters were measured using the Kimo AQ200 meter (OneTemp Pty Ltd): air temperature, globe temperature, wind speed and relative humidity.

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