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Human susceptibility to outdoor hot environment

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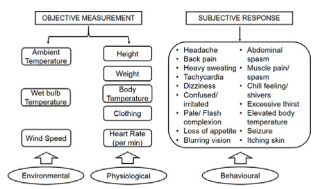
HIGHLIGHTS

- Explore the effectiveness of human thermal indices in the tropical climatic region
- Encoding heat-related perceived symptoms and disorders of the outdoor farm workers
- Assessing climatic susceptibility based on thermal indices, subjective and objective responses.

GRAPHICAL ABSTRACT



Parameters used to assess human thermal stress

Level of stress	Response					PET					PMV				
	Nov	Dec	Jan	Mar	Apr	Nov	Dec	Jan	Mar	Apr	Nov	Dec	Jan	Mar	Apr
Comfortable	41	31	27	7	7	0	9	6	0	0	0	34	29	0	0
Warm	40	37	43	27	39	0	71	93	0	0	4	46	65	0	0
Hot	14	20	25	38	39	100	20	1	100	0	65	20	6	0	0
Very hot	4	12	6	22	15	0	0	0	0	92	31	1	0	39	0
Sweltering	1	0	0	6	0	0	0	0	0	8	0	0	0	61	100

Percentage of the population at different thermal stress levels and climatic susceptibility

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ABSTRACT

A cross-sectional study examined the human susceptibility of a sample farmworker (N = 1144) in eastern India, who were exposed to the tropical hot outdoor environment during paddy and potato cropping activities (November to April). The study explored the efficacy of human thermal indices in human susceptibility categorization, based on analysis of indices, such as WBGT, HI, Humidex, UTCI, PET, SET*, PMV, and objective and subjective responses to heat-related symptoms and disorders. Analysis indicated dissimilarities in the estimated temperature levels of indices, attributed to different numerical weights of the meteorological and behavioural parameters. Therefore, the study explored the thermal stress level identified by different indices. December and January were recognized the comfortable months by most of the thermal indices. March and April were strong to very strong heat stress, with exception noted for SET*. In comparison to rational indices, the E_{sk}, a thermoregulatory parameter, signified the relative change in the evaporative exchange with the increasing environmental warmth. The defined level of E_{sk} at ~200 W/sq·m corresponded to the comfortable temperature range within 19.5 to 22.5 °C for WBGT, PET, and T_a. Beyond this specific range of warmth, a proportionate increase in E_{sk} would result in cumulative heat-related symptoms of stress and strain. The study noted a sizeable number of farmworkers manifested moderate to high intensity of heat-related symptoms, with a relatively higher percentage in case of females. The principal component analysis yielded three principal components of heat-related responses, labeled as (a) physical fatigue and responses, (b) neural stressors, and (c) behavioural effects. Normalized component scores transformed into a generalized quantitative climatic susceptibility indicator may be applied to the moderate intensity of physical activity in the tropical hot and humid environment.

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1. Introduction

More than half of the world's population live and work in a tropical climate, facing adversity of sweltering hot and humid weather. With the changing climate and variability (Bennett and McMichael, 2010), the vulnerability of the population appears insurmountable, unless the scale and magnitude of the climatic impacts are better understood and strategies implemented to mitigating impacts. Concerns have been raised that humans exposed to the varied climatic environment respond differently to one's inherent thermoregulatory ability (Parsons, 2003), and manifest in epidemiological outbursts of health effects and increased rate of mortality (Kovats and Hajat, 2008) due to climate extremes. The climatic projections like RegCM (Regional Climate Model) (Beniston et al., 2007), ESM2M (Earth System Model) (Dunne et al., 2013), RCP (Representative Concentration Pathway) scenarios (4.5, 8.5) (Kjellstrom et al., 2016) evidently support about the increasing level of human susceptibility towards the changing environment.

The level of tolerance to the hot environment defines the degree of susceptibility with due consideration of one's physiological and behavioural characteristics, the physical activity performed and the state of acclimatization to climate exposure (Nag et al., 1997). Concerning human exposure, researchers from different domains (atmospheric science, architecture, physiology) expressed that the climatic scenarios in the form of human thermal stress and strain indices, as cumulative of multiple physical and behavioural dimensions (Epstein and Moran, 2006; Carlucci and Pagliano, 2012). Emphasis goes in evolving and promulgating thermal exposure limit values of such indices (ISO 7243, 2003; ISO 7933, 1989; NIOSH, 1986) to ascertain the thresholds of exposure to the hot environment (Blazejczyk et al., 2012).

A mounting number of studies explored different human thermal indices to predict human susceptibility, taking into view that the humans supposedly become susceptible or vulnerable when the exposures cross the threshold limits as specified by different indices (Kjellstrom et al., 2013; Lundgren et al., 2014). For example, the HOTHAPS (High Occupational Temperature Health and Productivity Suppression) study in South African hot outdoor environment recognized the difficulties faced by the workers based on the perception of different working groups (Mathee et al., 2010). The indices, like WBGT (Wet Bulb Globe Temperature) and HI (Heat Index) were used to relate to heat-exposure related symptoms, such as heat cramps, exhaustion, and heat stroke in different industrial, agricultural, and construction sectors in Thailand (Langkulsen et al., 2010). Nag et al. (2007) established the decreasing trend of tolerance time of the tropical farmers in India with the rate of increasing WBGT temperature. By a similar approach, human susceptibility in terms of working hour loss has been reported considering the exposure limit criteria of WBGT (Kjellstrom et al., 2009; Dash and Kjellstrom, 2011). People exposed towards the uncontrolled environment are relatively more susceptible than those in the indoor environment (Kjellstrom et al., 2013). However, studies are scanty on the validation of reference exposure guidelines of different heat stress and strain indices, about the tropical hot outdoor environment and determining the level of human susceptibility in the dynamic climatic situations. This contribution elucidates the human responses to exposure to the outdoor tropical climate and further explores the approaches to express human susceptibility to hot climate quantitatively.

2. Methods and materials

2.1. Study location and sample population

The study was undertaken in the rural areas of eastern India, i.e., Hooghly and Burdwan districts of the state of West Bengal that situated on the right bank of river Ganges (Fig. 1). A large population of this area is habitually engaged in paddy and potato farming activities, under the direct exposure of the sun. Primarily the time of the study was chosen considering cropping seasons in the area, i.e., during the months of November to April 2015 to 2017. The farmers spend about 8–9 h a day in farm activities, usually beginning from the early morning, splitting at the midday for a lunch break and again continuing work in the later part of the afternoon.

A total of 1144 people participated in the study (632 male and 512 female farm workers). Brief details of the workers in different age ranges are given in Table 1. Female members had an average body weight of ~47 ± 8 kg with the ~153 ± 7 cm body height, and male members had ~54 ± 9 kg and ~164 ± 6 cm respectively. Some of the

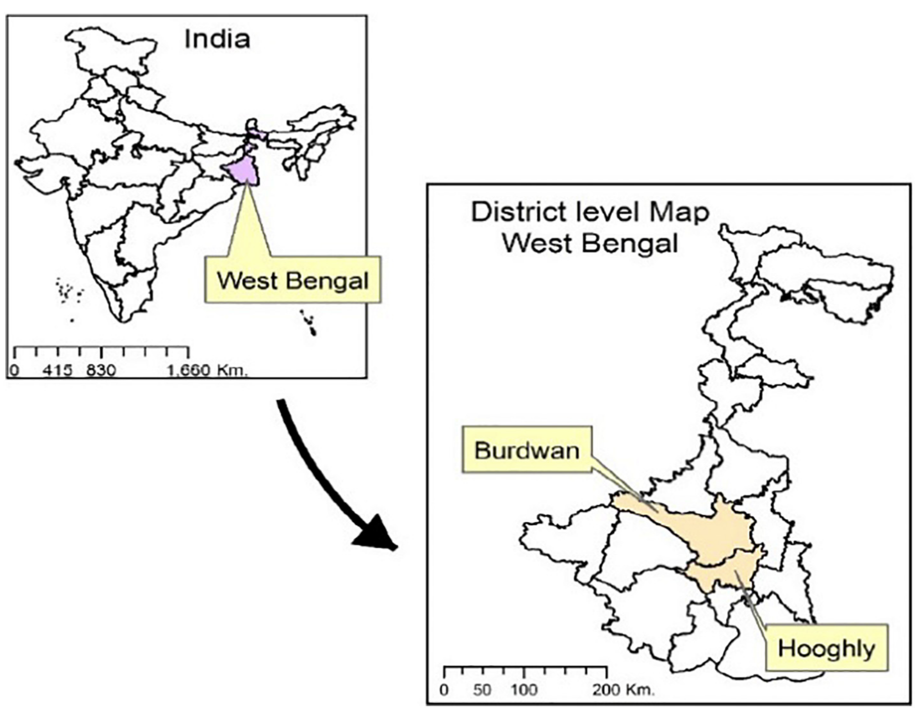

Fig. 1. Location map of the surveyed area.