Ethnic differences: The influence of relative humidity on thermal perception

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ABSTRACT

Field studies have shown that populations from tropical climates are better able to tolerate high humidity (>80%) conditions. This finding is contrary to physiology literature, which indicates no genotypic differences between ethnicities exist. The extent to which ethnicity influences thermal perception in humid environments remains unknown. To determine a definitive standpoint is challenging, given the various methodologies, environmental conditions and metrics used in previous studies. Here, we compare thermal perception between two ethnic groups in highly-controlled steady-state conditions at multiple relative humidities. Twelve body-matched Chinese (from central and southern China) and white-British males completed five 30-minute climatic chamber trials (25°C 35%; 25°C 85%; 29°C 35%; 29°C 65% and 29°C 85%). Metabolic rate and clothing insulation remained constant. Thermal perception was measured using a battery of psychological scales. Physiological responses were monitored throughout each trial. After 30-minutes, there were no significant between-group differences in the physiological responses and most psychological results obtained. A difference in wetness sensation was observed for the warm-high humidity (29°C, 85% RH) condition only, where Chinese males rated approximately one scale-unit higher (*wet*) than British males (*slightly wet*). The results indicate British and Chinese males respond predominantly in the same way to their thermal environment. Although, Chinese males did perceive the warm, humid environment as being wetter. Given the lack of human hygroreceptors, it is unclear what is driving this increased perception of wetness. It could be linked to thermal history and behavioural expectations; both considered responsible for differences observed between field and controlled laboratory studies.

KEYWORDS

Thermal perception, ethnicity, humidity

Introduction

Field studies comparing ethnic differences in thermal sensation responses have reported that populations from warm, humid climates better tolerate high humidity conditions (Mom et al. 1947; Ellis 1950, 1953; Knez and Thorsson 2006). Ellis (1953) sought to examine preferred levels of warmth between Europeans and Asians in Singapore. Thermal comfort surveys were distributed to individuals with European ancestry (British and Australian nationals) who had resided in Singapore for at least six months and individuals from across multiple Asian countries (e.g., China, India, and Malaysia). Participants were required to record indoor dry and wet-bulb temperatures and their corresponding thermal comfort level at any time of day. The European group were less tolerant of the warm, humid comfort zone conditions overall, and were most comfortable in these conditions

whilst sedentary and wearing light clothing. Knez and Thorsson (2006) conducted a quasi-experimental study to examine ethnic differences in thermal perception between Japanese and Swedish citizens in public squares located in Göteborg, Sweden (mean air temperature: 20.3°C; mean air velocity: 1.6 ms-1) and Matsudo, Japan (20.7°C; 1.0 ms^{-1}). Swedish individuals reported an almost neutral thermal sensation, while Japanese volunteers were closer to feeling slightly warm. The Japanese inhabitants were thermally less comfortable, although they estimated the weather as being warmer.

One major drawback of using field studies as an approach to exploring ethnic differences in thermal perception is the potential variation in confounding factors. The studies have attempted to account for these by obtaining details on clothing worn, food consumption, time of day and activity level (Ellis 1953; Ballantyne et al. 1979), but individual differences such as age and sex, as well as body size and composition, have also been implicated in thermal perception responses (Shipworth et al. 2016; Wang et al. 2018). However, several laboratory studies support the existence of ethnic differences in various thermal perceptual responses (Lee et al. 2011; Maiti 2013; Havenith et al. 2020). Remarkably, support for ethnic differences contradicts physiology literature, which indicates no genotypic differences between ethnicities exist (Taylor 2006). Thus, the extent to which ethnicity influences thermal perception in humid environments remains unknown.

Given the various methodologies, environmental conditions and metrics used in previous studies, it is difficult to draw a definitive conclusion. Although previous research has been conducted to explore human thermal responses in various air temperature and relative humidity combinations, no single study has directly compared different ethnic groups in highly-controlled body-matched climatic chamber trials. Such methodology would confirm any presence of physiological and psychological differences in thermal perception between ethnic groups. The study aimed to determine the influence of ethnicity on thermal perception at various relative humidities. In highly controlled laboratory conditions, physiological and psychological responses from two ethnically homologous groups were examined.

Methods

Six Chinese and six white-British males were body-matched by body mass index (BMI) within ±1kg. All recruits were required to have lived in the United Kingdom, without overseas travel, for three months before the study. Limitations on activity level and food consumption were imposed prior each trial. A set clothing ensemble, equal to an insulation value of 0.5 clo (short-sleeved t-shirt, trousers, socks, running shoes) was worn. Five experimental conditions were examined in a counter-balanced order: neutral-low (25°C 35% RH), neutral-high (25°C 85% RH), warm-low (29°C 35% RH), warm-moderate (29°C 65% RH) and warm-high (29°C 85% RH), with each trial lasting sixty minutes.

Participants spent thirty minutes in a thermoneutral room to physiologically stabilise. At the end of the stabilisation period, physiological (Local skin temperatures, mean skin temperature, tympanic temperature, heart rate and skin hydration) and psychological (thermal sensation, thermal comfort, thermal preference, pleasantness, stickiness and wetness sensation) measurements were taken. The participants then moved into a climate-controlled environmental chamber and exposed to the experimental conditions for thirty minutes. To maintain a steady activity level during the trial, participants remain seated. Physiological and psychological responses were repeated immediately upon entry to the chamber and every five minutes until the end of the thirty-minute trial.

Results

The environmental conditions were highly-controlled across all experimental conditions, as shown in Table 1 below. Physiological and psychological measurements taken throughout the 30-minute exposure to the experimental conditions. The 30-minute end values are presented in Table 2.

Table 1: Mean environmental conditions and standard deviations.

	Condition	T_a (°C)	RH (%)	Measured T_a (°C)	Measured RH (%)
1	neutral-low	25	35	25.3 ± 0.0	34.8 ± 0.8
2	neutral-high	25	85	25.1 ± 0.4	85.1 ± 0.9
3	warm-low	29	35	29.3 ± 0.3	35.0 ± 0.7
4	warm-mod	29	65	29.2 ± 0.2	64.9 ± 0.4
5	warm-high	29	85	29.3 ± 0.1	85.3 ± 0.4

Table 2: Summary of mean physiological and psychological measurements taken after 30-minutes for British males (Br) and Chinese males (Ch).

	25°C				29°C					
	Low		High		Low		Moderate		High	
	Br	Ch	Br	Ch	Br	Ch	Br	Ch	Br	Ch
Mean Skin Temperature (°C)	33.8	33.6	33.9	33.9	34.7	34.4	34.5	34.6	34.6	35.0
Skin Hydration: Forehead (PWC)	52.2	57.2	58.5	61.2	56.5	59.3	59.0	61.0	62.5	68.0
Skin Hydration: Forehead (TDC)	38.2	28.5	61.7	64.8	47.2	38.8	64.2	76.3	103.8	119.5
Thermal Sensation*	1.7	7.3	5.0	5.0	11.7	16.7	25.0	15.0	21.7	21.7
Thermal Comfort	0.2	0.5	1.0	0.7	0.8	1.2	1.8	2.0	2.8	3.5
Thermal Preference	0.2	-0.5	-0.2	-0.2	-1.0	-0.8	-1.2	-1.3	-1.8	-1.5
Stickiness	0.2	0.3	1.0	1.0	0.2	0.5	2.5	1.7	3.0	3.8
Wetness	0.2	0.5	0.8	1.0	0.3	0.5	1.8	2.0	2.3	3.8
Pleasantness	0.7	0.5	-0.2	0.0	0.2	-0.6	-1.2	-1.0	-1.3	-1.7

*To provide greater sensitivity for the ratings of Thermal Sensation the scale was increased by 10, so 2 Warm = 20 Warm

Physiological measurements

There were no significant differences in physiological responses between the experimental groups, across conditions. The Chinese males did repeatedly demonstrate higher skin hydration across all environmental conditions. Figure 2 presents the percentage water content (PWC) and tissue dielectric constant (TDC, an arbitrary unit) skin hydration results for the forehead in the warm-high condition. Chinese males had higher forehead PWC (Br: 62.5 ± 5.6; Ch: 68.0 ± 2.6; $P = 0.053$) and TDC (Br: 103.8 ± 30.2; Ch: 119.5 ± 24.9; $P = 0.350$) than British males. However, these effects were not statistically significant.

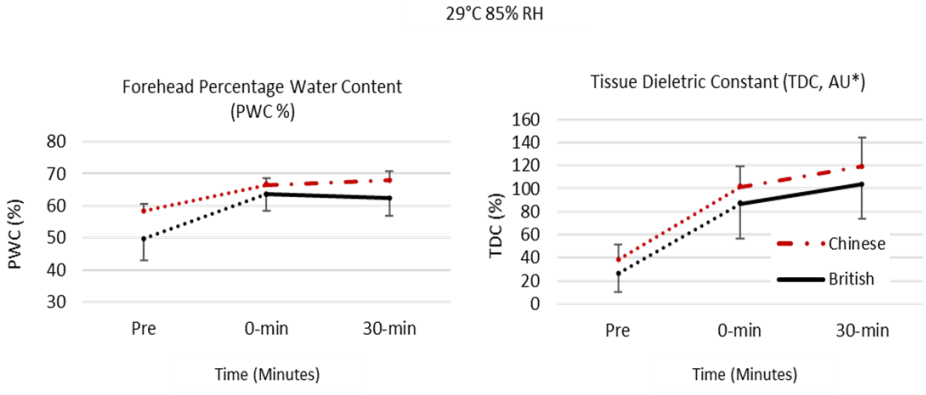

Figure 1: Skin hydration results for the warm-high humidity condition (29°C, 85% RH) for the 30-minute trial duration.

Psychological measurements

After thirty minutes of exposure, no significant differences ($P > 0.05$) were found between each ethnic group for the following psychological metrics: thermal sensation, thermal comfort, thermal preference, stickiness or pleasantness, for any condition. A notable difference in wetness sensation level was observed at multiple time points in the warm-high condition only, as illustrated in Figure 2. For example, at 10-minutes, Chinese males reported a '*wet*' sensation (3.7 ± 1.6), while British males reported feeling '*slightly wet*' (1.7 ± 0.8; $P = 0.042$).

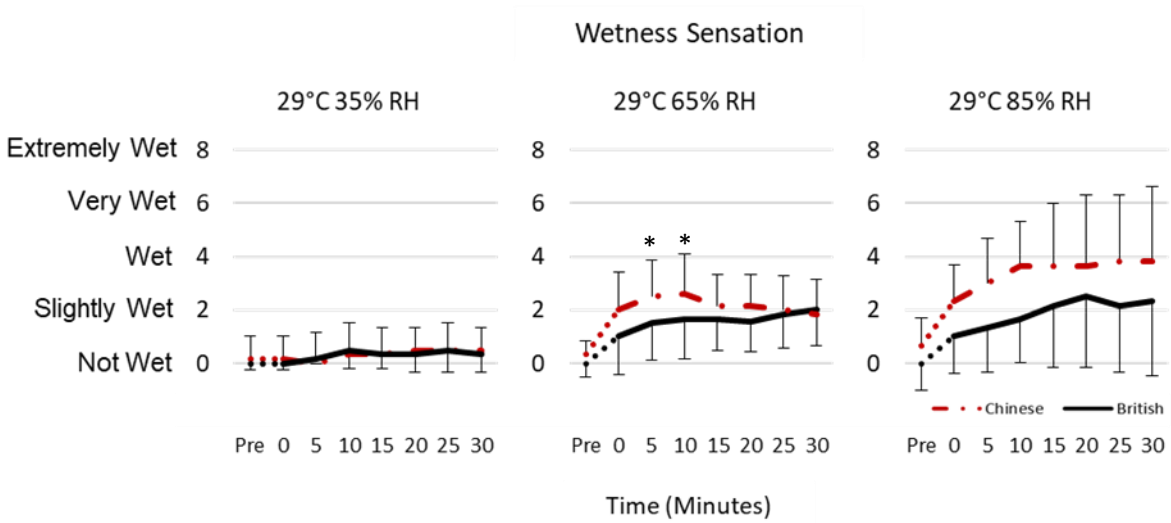

Figure 2: Wetness sensation response obtained at intervals during the trial for the warm trials (warm-low, warm-moderate and warm-high). *Significance $P < 0.05$.

Discussion

The principal research question was to determine the influence of ethnic differences on thermal perception and how it changes with relative humidity level. The diversity of research methodologies used in the past to investigate this phenomenon make it difficult to determine the basis for the observed differences. This study took a highly controlled experimental approach to systematically examine this concept using a wide range of physiological and psychological measurements. The main finding in the study is that no significant differences between each ethnic group for the following psychological metrics: thermal sensation, thermal comfort, thermal preference, stickiness or pleasantness, for any condition. This finding shows that when body-matched individuals in controlled environments, clothing and metabolic activity levels, there is minimal difference in most subjective thermal perception metrics.

The one subjective factor that where there was a difference between ethnicities was wetness. The Chinese group reported stronger wetness sensation responses than for the British group across all conditions. Immediately upon exposure to the test conditions, the Chinese reported a statistically higher wetness rating than the British group for all conditions. Although, significant differences were only identified in the warm-high humidity condition (29°C, 85% RH). The underlying mechanisms of sensing skin wetness (i.e. hygrosensation) was examined in Filingeri et al. (2014) and (Filingeri and Havenith 2015). Humans lack skin humidity receptors (hygroreceptors) to discern wetness and humidity cutaneous sensations, but do so successfully, as demonstrated in the current and in previous studies (e.g., (McIntyre 1978; Jin et al. 2017). It is proposed that the ability to detect wetness is a learned response based on prior sensory experience, derived from a complex integration of somatosensory cues (e.g., from thermoreceptors and mechanoreceptors) (Bergmann Tiest et al. 2012; Filingeri et al. 2014; Filingeri and Havenith 2015).

Ethnic differences in wetness sensation appears to have not previously been reported in the literature. A possible explanation for this finding is the notion of perceptual inference, a top-down Bayesian approach in which deductions about external sensory stimuli are predicted from a bank of stored neural representations (Filingeri et al. 2014; Aggelopoulos 2015). Neural representations are developed via long-term associations from previous experiences, and as described by operant conditioning (Skinner 1963), are involuntarily stimulated when evoked by external stimuli. The two ethnic groups used in the current study were born and raised in distinctly different climates. According to the Köppen climate classification system (Kottek et al. 2006; Waycott et al. 2014), the white British group would be accustomed to a temperate oceanic climate (Cfb).

In comparison, being from regions across central and southern China, the Chinese group would be familiar with a hot summer, humid continental climate (e.g., Beijing: Dwa; Shanghai: Cfa). Therefore, it may be that these two ethnic groups have attuned long-term neural representations based on their respective typical thermal environments. For the Chinese group, stronger, rapid onset sensations could result from a more honed response due to frequent exposure to high humidity conditions.

Overall, the study shows that minimal differences in physiological and psychological responses (except for wetness sensation) exist between ethnicities when physical, environmental and personal factors are controlled. However, this finding conflicts with the notable difference in preferred air temperatures between British and Chinese groups (Havenith et al. 2020). Thus, the disparity may be explained by the ability to control the environment, in which aspects that are influenced by ethnic background (e.g., thermal history and thermal expectation) may influence the choices made.

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