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Diurnal temperature changes and physiological experience of students under indoor condition in a Nigerian University

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ABSTRACT

This study characterized the daytime thermal condition (in terms of the ambient air temperature change) of a University campus in southwest Nigeria, and examined the perception of students in the halls of residence on thermal condition and their strategies for coping with extreme thermal cases. Data used included air temperature, relative humidity as well as body temperature and weight of randomly selected subjects from halls of residence. Data also included the perception of selected students on thermal comfort or discomfort. Diurnal thermal range varied between 32.4°C and 35°C in the morning and between 26.5°C and 30.9°C in the evening. Thirty-five (35%) percent of the subjects (young male and female students, aged 18 – 45 years) associated thermal discomfort with restlessness and profuse sweating but 13% did not feel any significant thermal stress within the study period. Also, effects of thermal stress varied diurnally; whereas 65% of the subjects experienced heat rashes and headache in the evening and afternoon, respectively, about 10% experienced profuse sweat and chest constriction in the morning. Lastly, perception of thermal stress varied with room temperature, subjects' body weight, period of the day and ventilation. The study concluded that thermal discomfort in the area is influenced by indoor and outdoor atmospheric conditions as well as subjects' physical and physiological characteristics.

Keywords: Indoor characteristics; Thermal stress; Temperature; Physiology; Perception

1. INTRODUCTION

Thermal comfort is an important part of survival behavior through which the human body responds to temperature change (Nagashima, 2018). Whereas typical human body maintains a core temperature within a narrow range of 37° C, humans react to changes in environmental temperature with alteration in body conditions and some other physiologic factors (Fuller et al., 2021). Body actions to thermal comfort can be conscious or subconscious. The American society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE, 1981) defined thermal comfort is the condition of the mind that expresses satisfaction with the thermal environment. It is also the absence of discomfort, when a person feels

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neither too warm or cold (McIntyre, 1980). Jauregui (1993) argued that most people would feel comfortable at room temperature (20-22^{o}C) and that variations occurs with different individuals and personal attribute level, including activity level, clothing, and humidity. Perception on thermal comfort is typically defined in terms of the physical, psychological sensations generated by the thermal environment stimuli, activity, clothing, experience and human expectation (Aulicems, 1998). Main factors that influences thermal comfort are those that determine heat gain and loss (including metabolic rate, clothing insulation, air temperature, mean radiant temperature, airspeed and relative humidity), psychological factors (such as individual expectations and responses also affect thermal comfort; Schweiker et al., 2018). Thermal comfort may vary based on the location of the environmental condition; i.e. indoor or outdoor environment. Indoor spaces are important and contribute greatly to livability and vitality (Hakim et al., 1998); people are also not directly exposed to sunshade, changes in wind speed and other characteristics in the outdoor environment but are affected by the interaction between the medium of their building materials, and available infrastructure in the rooms and immediate environment. The relationship of physical parameters to physiological response of humans, however remains poorly understood (Hartmann & Bung, 1999).

A number of biometrological indices have been developed to describe human thermal comfort levels. Most of these indices are based on the assumption that people's exposure to an ambient climatic environment has enabled them to reach thermal equilibrium overtime (Nagano & Horikoshi, 2011). Examples of the indices include the Predicted Mean vote (PMV) (Fanger, 1982) which predicts the mean thermal response of a large population of people.it is often measured on a seven-point scale (hot, warm, slightly warm, neutral, slightly cool, cool, cold) or Predicted Percentage Dissatisfied Index (PPD), which is defined as the quantitative prediction of the percentage of thermally dissatisfied people at each PMV value. The PMV was originally developed as an indoor thermal comfort index, but has also been commonly adopted in outdoor thermal comfort studies in which a large group of people are being surveyed (Cheng et al., 2010; Nikolopoulou, Baker and Steemers, 2001). Similar subjective method is the Physiological Equivalent Temperature (PET) (Mayer and Hoppe, 1987) which is the air temperature at which, the human energy budget is maintained by the skin temperature, core temperature and sweat rate equal to those under the conditions to be assessed (Hoppe, 1999). The indices translate the valuation of a complex outdoor climatic environment to a simple indoor scenario on a physiologically equivalent that can be easily understood. The subjective indices have been combined with climatic data to assess human thermal response to the local environment (see Eludoyin et al, 2014; Eludoyin, 2015).

Research Problem

Given the increased concerns of the effects of thermal comfort indices on man has translated into research, many researchers have attempted to understand the views, severity and implications of these effects as well as seeking to understand how people cope with them (Jauregui, 1993). An understanding of the nature of thermal comfort index of a region or area is important. This ensures a better understanding of the thermal conditions and comfort of the people. The on the University environment is underpinned by the assumption that ivory towers should serve as template from which communities can learn. Students are also characterized by diverse demographic, social and economic background, and as such, understanding their perceptions and feeling under similar climatic conditions encouraged curiosity about varying perceptions and coping strategies, hence this study. Specific objectives are therefore to examine the perception of a set of systematically selected students on thermal condition in their University (Obafemi Awolowo University, Il-Ife, Nigeria), characterize the diurnal thermal condition in the study area and examine prominent coping strategies against thermally uncomfortable weather/climatic condition.

Study Area

The study area, Obafemi Awolowo University campus in the southwestern Nigeria (Figure 1), has a population of over 30,000 students and many hundreds of staff (Olupona, 2011). The area is climatically distinguished by two distinct seasons; wet/rainy and the dry seasons, which is experienced April - October and November-March, respectively. Mean annual rainfall is about 1237 mm (Bayowa et al., 2011). The vegetation is naturally rain forest but now has many areas that are covered by herbs, grasses and light forest due to human interferences. Analysis of the land use pattern suggests that the built-up area of the campus can stratified into Students' residences, Staff quarters, and Administrative and Academic area, which consists of administrative blocks, classrooms, amphitheater and other hall facilities, library, student union building and places for entertainment, recreation and sports. Students' accommodation facilities (halls of residence) are separated from the Academic and Administrative blocks. Cafeterias and markets are also separated to another section of the University land while staff quarters and an extensive land for agriculture and land/water-related researches are made to occupy a large space on the University campus, as well. The staff quarters contain over 500 housing units for senior academic and administrative staff and more than 30 semi-detached units for junior staff. Junior staff quarters are located towards the end of "Road 7" linking the campus with the city of Ile-Ife via the 'Second Gate'. The staff quarters are well planned with great care; the uniformly consistent and attractive environment, based on the principles of garden city planning features, is planned to give a sense of belonging (Egboramy, 1981). The Students halls of residence include, Awolowo, Fajuyi, Postgraduate/Murtala Mohammed, Angola, Mozambique, Moremi, Ladoke Akintola/Sport, Education Trust Fund/ETF and Alumni Halls. Each hall is capable of accommodating between 1,000 and 5,000 students.

Figure 1. Obafemi Awolowo University, Ile-Ife (Adapted from Babatimehin et al., 2020)

2. MATERIALS AND METHODS

Data used for this study included the ambient air temperature, taken at different period of the day (0800 – 1000 and 1600 – 1800 Local Standard Time, which are peak periods of activities in the University). Data also include responses of a purposively selected participants on feelings, thermal discomfort and coping strategies, as well as their body characteristics. Selected participants were male and female students, aged 18 – 45 years. Responses were obtained from participants in halls of residence, following a multistage procedure;

- Seven halls of residence were systematically sampled, considering gender, level of dominant residents (postgraduate versus undergraduate halls) and location (based on compass direction).
- From selected halls, three blocks of rooms (1st, 50th and 99th rooms) at the upper and lower floors were targeted for even distribution and understanding of thermal conditions.
- In all, a total of 98 copies of questionnaire were administered in the hostels; two (Angola and Mozambique) has only one floor - bungalow buildings.
- Air temperature and relative humidity were obtained using handheld thermometer and hygrometer, while perception on using a set of structured questionnaires. Also, a handheld Global Positioning System (etrex version) was used to take the coordinates of the halls of residence and specified locations in the study area. Body temperature of the participants and their weight were measured using clinical thermometer and a mechanical bathroom weight measuing scale, respectively. Results were analysed using isotherms and percentage distribution.

3. RESULTS AND DISCUSSION

3.1. Outdoor and indoor air temperature changes

Outdoor air temperature varied more in the evening than the morning time across the university campus, and surprisingly the morning time was warmer than the evening time, although the evening time showed more variability (27°C – 30.9°C compared with 32.3°C – 35.2°C) (Figure 2). Higher outdoor temperature during the morning-time suggests that heat generating activities may

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be more in the morning than the evening. Students cook more in their hostels, and the movements to attend lectures appear to be at peak in many days. The study period was within the lecture periods of the University, when students often rush to attend classes, and when many practical activities were taking place, outside the halls of residence. Also, vehicular activities at this period also peaked throughout the university campus unlike in the evening when most of the activities may be concentrated towards the exit gates, when workers leave for their homes. Figure 2 also shows that areas around the halls of residence had higher outdoor temperature, suggesting an impact of activities in the residential halls of residences.

Figure 3 shows the variation in the mean room temperature across the selected halls. Room temperature appeared to vary with location, i.e. surrounding environment of the halls. Temperature tend to decrease as one moved away from one of the halls (although highest at Angola) towards the academic areas in the morning. Angola hall houses 100 level undergraduate students, and the journey to the academic area requires passage through all the other halls, except Ladoke Akintola/Sport and ETF halls. Average indoor temperature however dropped/decreased at Moremi hall. Moremi hall is surrounded by relatively more open space than the other halls, and characterized with extensive grassland.

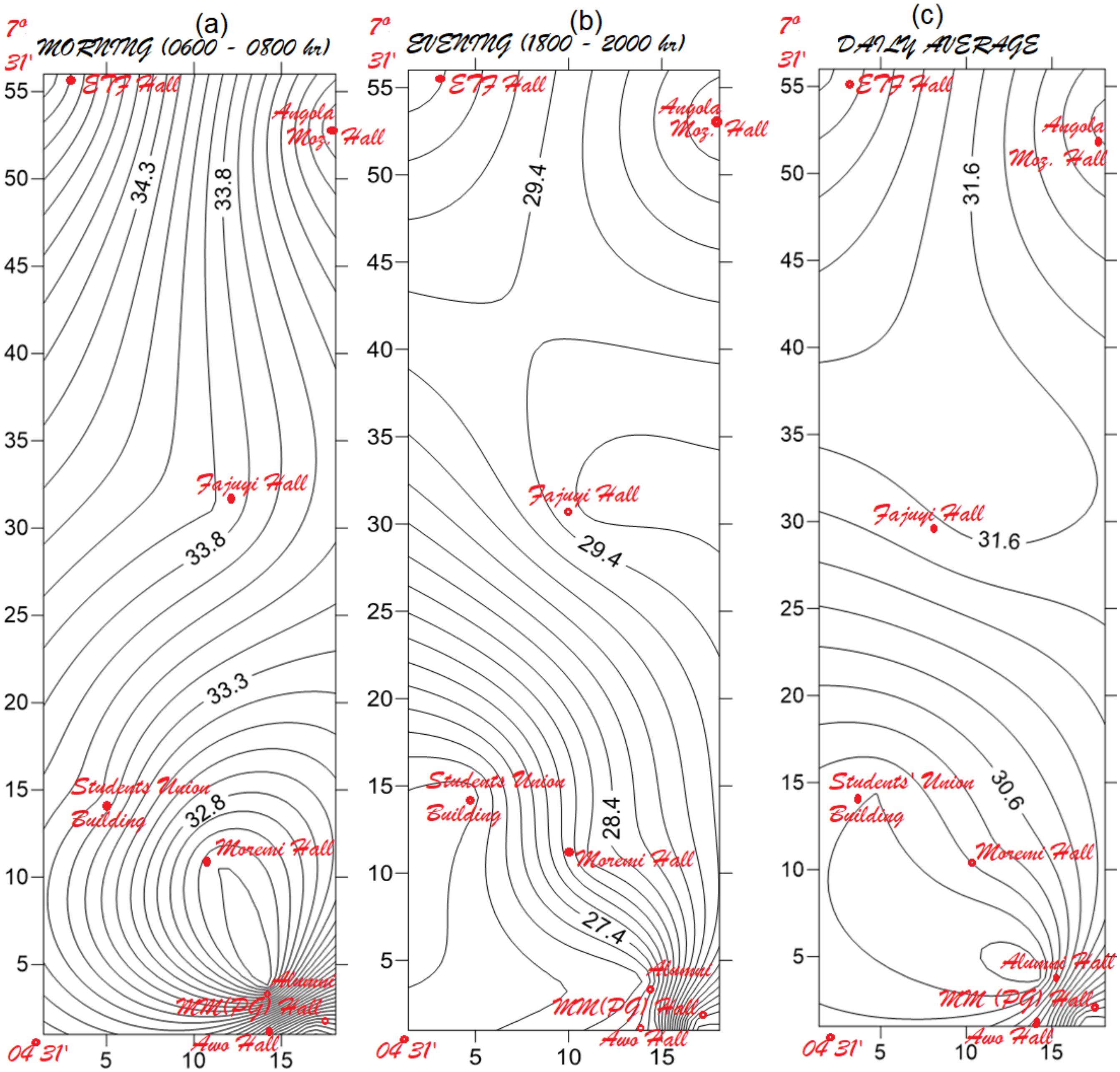

Figure 2. Time variant and average daily isotherm distribution across the University area

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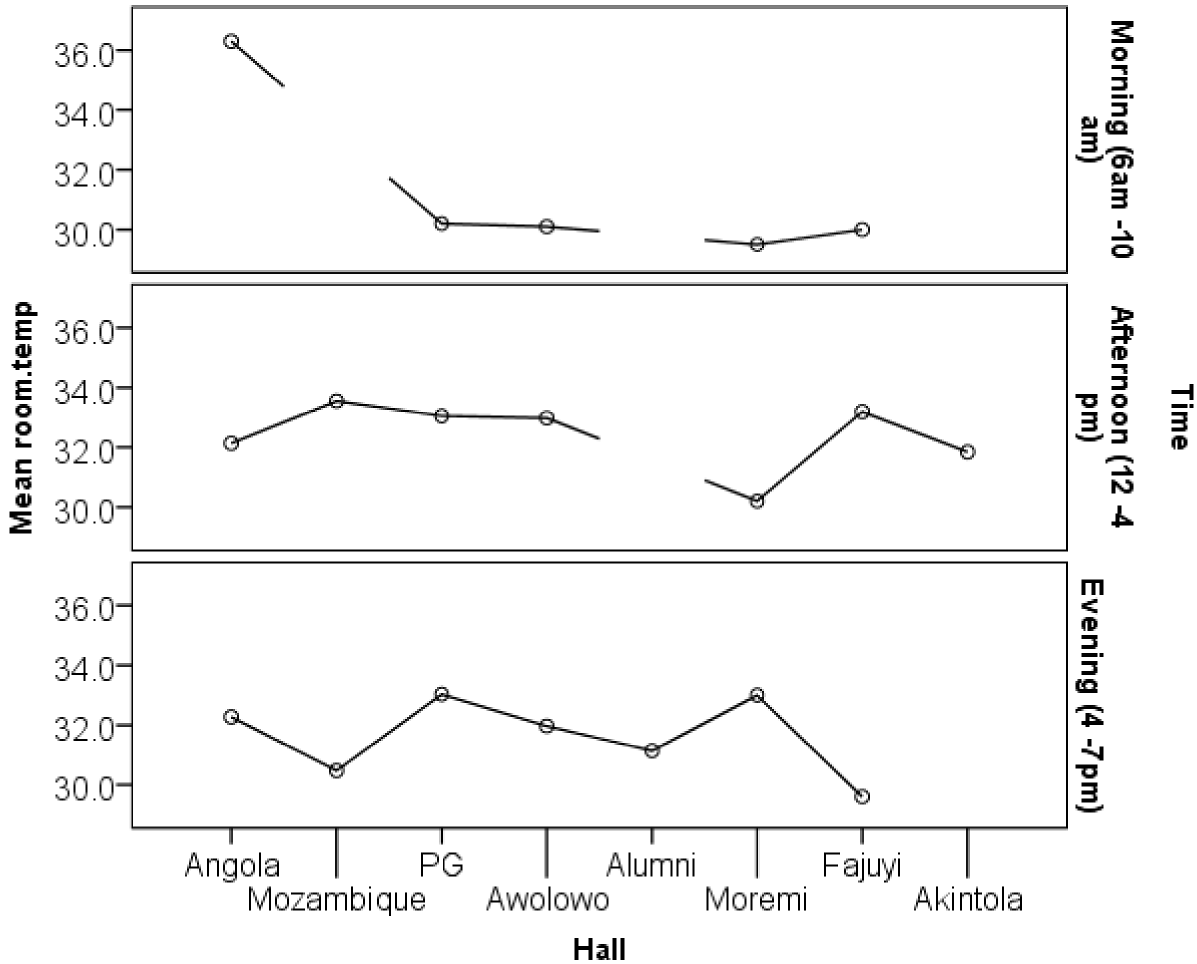

Figure 3. Mean daily indoor/room temperature across selected halls in the University campus.

3.2. Heat condition and perception in the hostel rooms

Less than average (45.8%) of respondents resided in rooms without fan, and 34.5% were found discussing/chatting at the time of the study. Others were either doing nothing/lying down (resting) will only few (< 7%) were found studying (Table 1). Over 70% described the rooms at the time of the study as either warm or hot (41.2% and 39.1%), probably because the study occurred in the dry season (March 2018). Comparison of the effect of the presence or absence of ventilation (either uncovered, with fan or without a fan) suggest that body temperature tend to be differently modulated by fan and natural air (Figure 4).

Table 1 Situation Attributes of respondents

Variable	Option	Frequency	Percentage (%)
Gender	Male	122	43
	Female	162	57
Description of location	Partially uncovered	36	12.7
	Room with fan	118	41.5
	Room without fan	130	45.8
Activities at interview	Resting	64	22.5
	Chatting	98	34.5
	Reading	23	8.1
	Sitting	17	6.0
	Watching a movie	10	3.5
	Studying	19	6.7
	Eating	14	4.9

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Cooking	26	9.2
Working	13	4.6

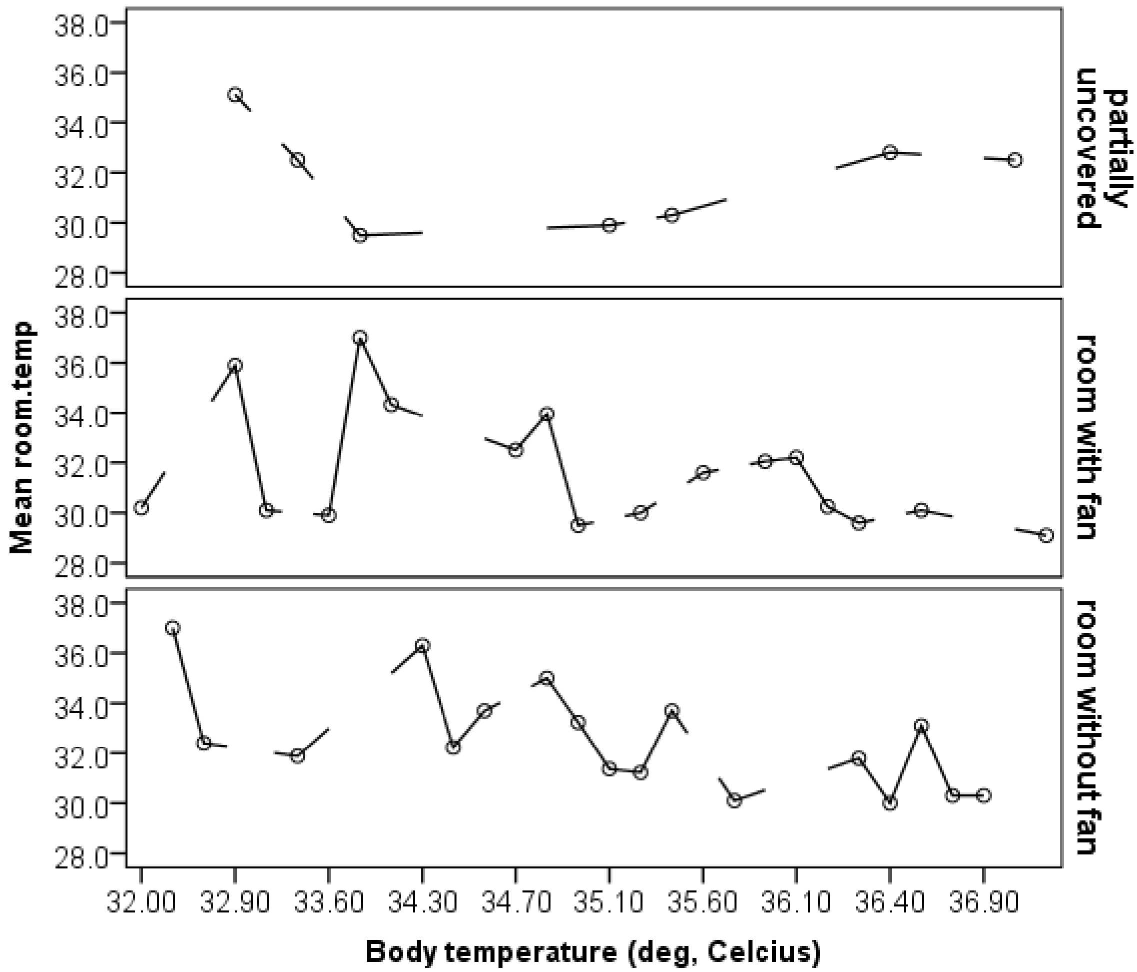

Figure 4. Change in body temperature with change in air temperature across different environment

3.3. Effects of heat

Relatively higher proportion of the participants complained of restlessness in the event of heat surge, others complained of increased level of perspiration or sweating, especially in the afternoon (Figure 5a). Figure 5b revealed that many of the temperature-related sicknesses exhibited temporal/diurnal variations. For example, more cases of tiredness, dizziness and sweating were recorded in the evening while heat rash and headache occurred more in the afternoon.

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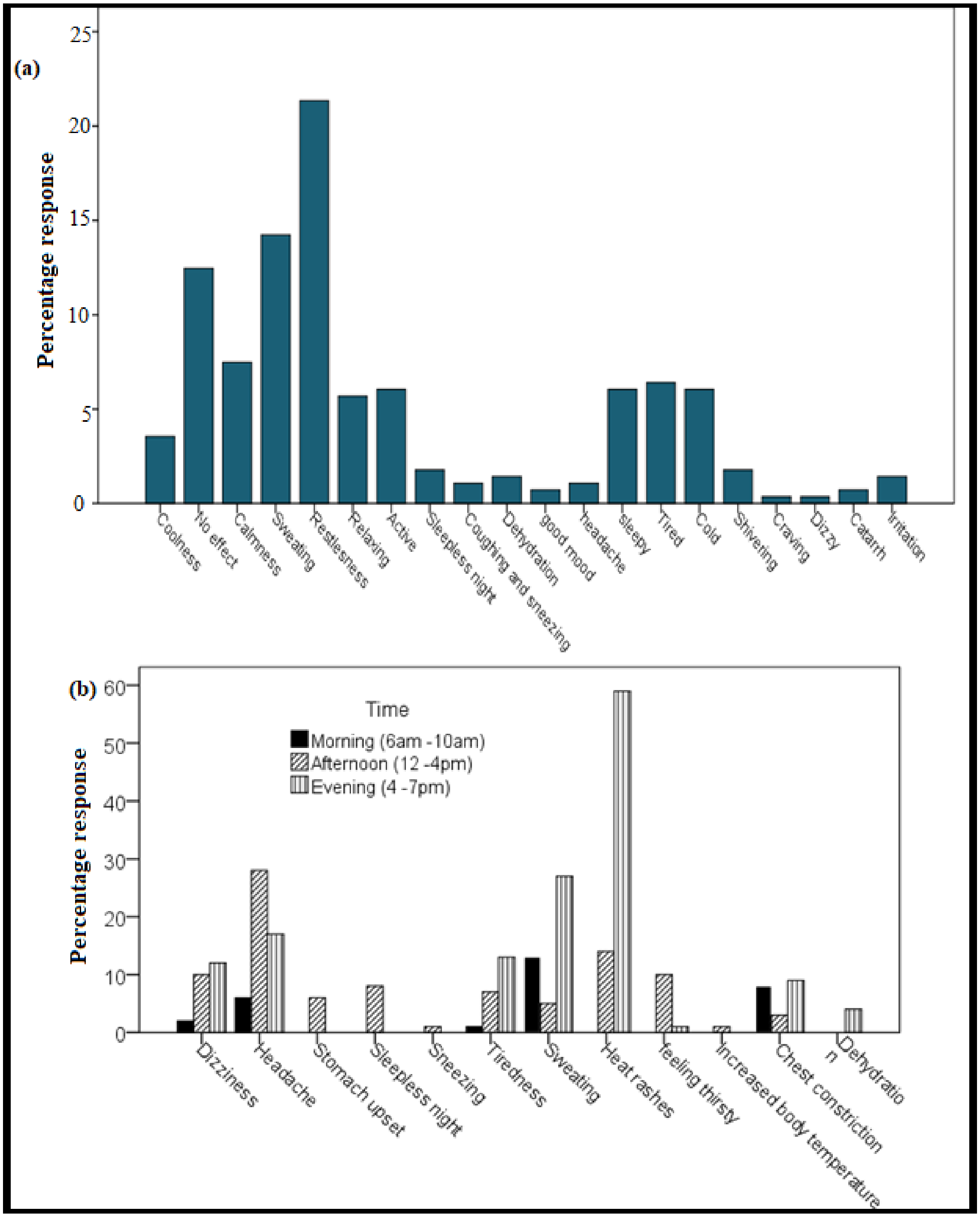

Figure 5. Reported effects (a) of high temperature and diurnal variations (b)

Furthermore, reportage of the effects appears to be gender biased, as majority of the participants that reported dizziness, headache and heat rashes were female while the male participants mostly reported chest constriction, sweating and tiredness (Figure 6a). Also, majority of those who claimed to sweat much were from the partially covered room and those who were restless were surprisingly from the rooms with fan (Figure 6b).

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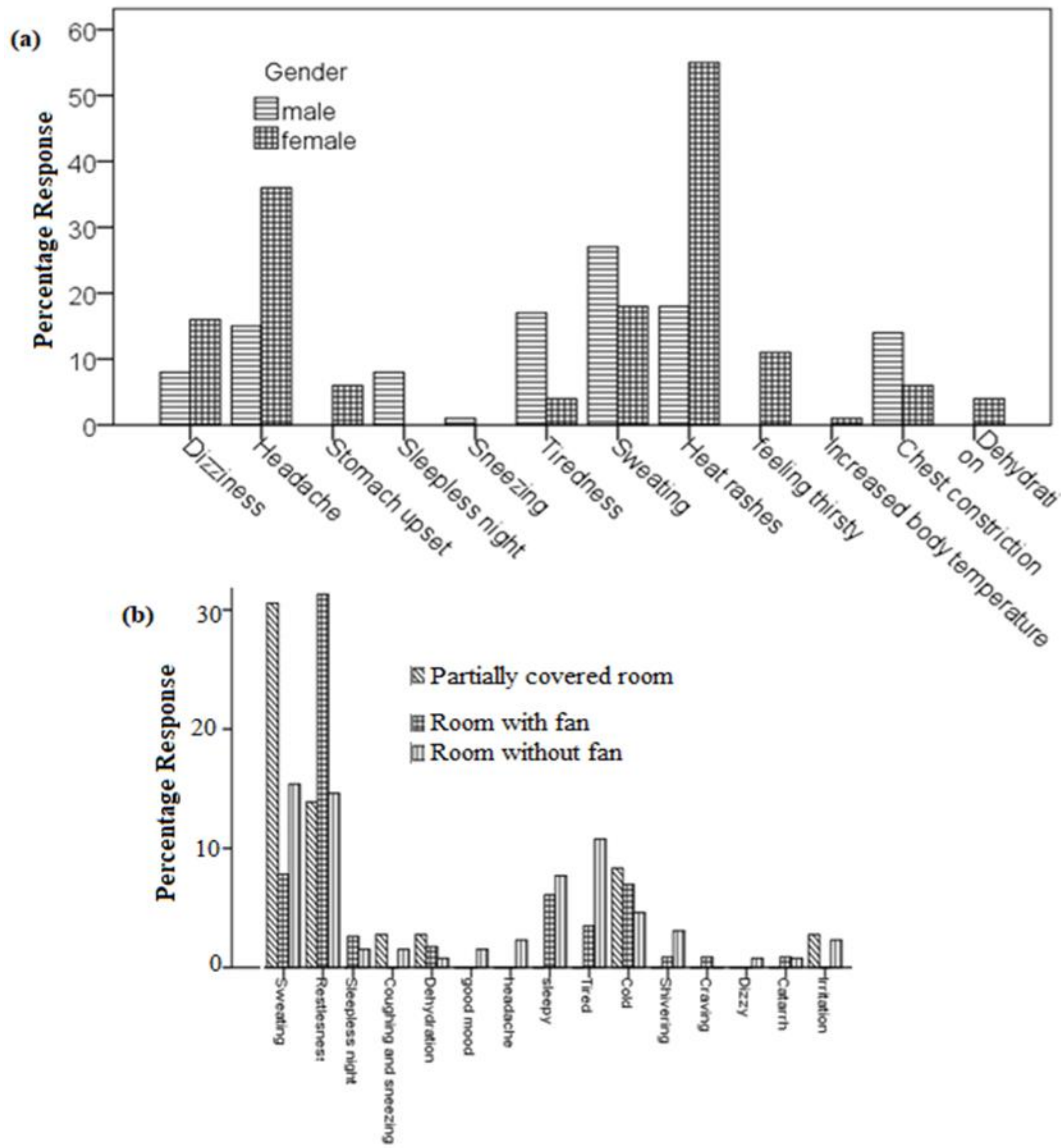

Figure 6. Perception on the role of gender and room type on physiological feeling

Apparently, no coping strategy was exhibited by the participants other than trying to be active, and or responsive to the prevailing temperature; such as taking shower when it is hot, using cover cloth when it is cold, taking nap, among others (Figure 7). Given this, and other information from majority of the participants, it became almost obvious that knowledge about physiologic climate and coping strategies is shallow. Many (over 42.2%) of the participants were actually new to the term, *thermal comfort, physiologic comfort or bioclimate,* and less than 20% considered heat stress a problem that require a major concern in the study area.

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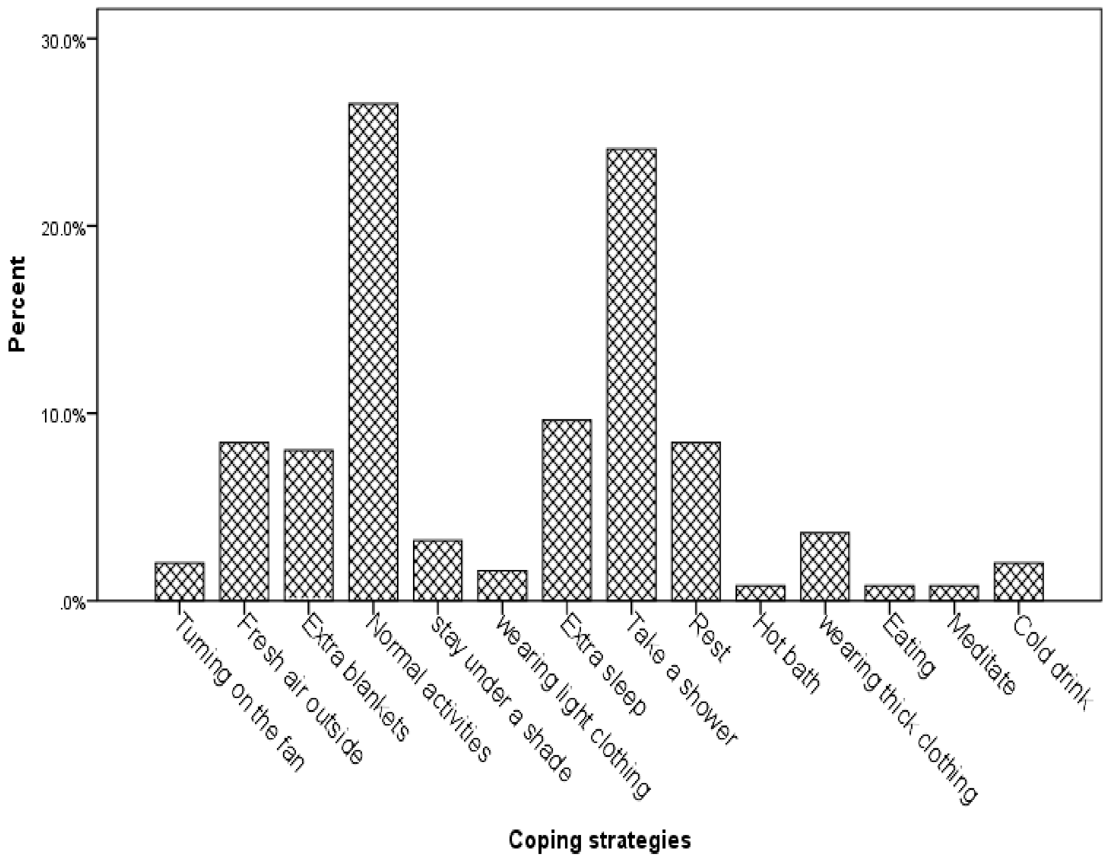

Figure 7. Coping strategies to extreme heat condition by participants

4. CONCLUSION

A number of issues emanating from this study indicate poor knowledge of physiological climatology, human biometeorology and thermal comfort among participants, who were University students at the time of study. The study revealed that surrounding environment, indoor condition as well as personal attributes of subjects are important in the discussion of thermal comfort. The study also showed the need for better understanding of the role of gender orientation, building materials, ventilation, among other variables that have been shown to be relevant to physiologic or thermal comfort in developed economies, as they relate to the sub-Saharan African countries. More experimental researches in the area of thermal comfort in the region is recommended to improve awareness to the effects of extreme temperature events, such as heat stress, heat stroke, among others. It is hoped that such improved focus on experimental research can improve innovative coping strategies for heat and/or cold stress events in the region.

Conflict of interest

The authors declare that they have no conflict of interest.

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Data and materials availability

All data associated with this study are present in the paper.

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