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Classrooms and comfort temperature in South East Nigeria

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Abstract

A field study was conducted in naturally ventilated public-school buildings located in the warm and humid climate of Imo State in Nigeria, to determine the comfort temperature of the schoolchildren. The survey took place from October 2017 to May 2018, covering rainy season and dry season, where objective and subjective approaches to data collection were employed. Results of the fieldwork of the 330 surveyed children (aged 7-12 years) revealed that the maximum comfort temperature derived from their responses corresponding to mean thermal sensations of +0.85, is 31.6°C for the combined classrooms. This is about 4.9°C higher than the ASHRAE upper 80% acceptability limit. Furthermore, when categorized according to season and time of day, the comfort temperature were also found to be higher than the ASHRAE upper limit. The study shows that respondents in a tropical country, such as in Nigeria, can be comfortable at high temperatures. The information on comfort temperature is important as that may guide professionals in the building industry to achieve eco-friendly and sustainable classrooms that use less energy and at the same time provide thermal comfort to the occupants.

Keywords: ASHRAE; Comfortable; Maximum temperature; Sustainable; Thermal comfort

1. Introduction

Our indoor spaces are becoming more and more overheated because of climate change. The earth's climate is changing at an accelerated pace and to an extent, human beings can only tolerate the heat stress depending on their survival strategy. The thermoregulatory responses of the human body play an important part as people try to adapt to temperature changes. To ensure that the internal body temperature is kept at 37°C, there is a continuous heat exchange between the human body and its environment. The major organ involved in heat loss is the skin, which is responsible for approximately 90% of heat loss (Koop & Tadi, 2019). There is some documented evidence about the effects of high temperatures on people. Exposure to high temperatures can cause health problems such as increased risk of heat stroke, respiratory and cardiovascular hospitalization (Anderson et al., 2013; Hoshiko, English, Smith, & Trent, 2010).

In schools, this rise in temperature is an issue and apart from the impact on pupils' health, it may affect their learning and problem-solving ability (Munonye & Ji 2021; Ricardo et al 2015; Singh et al 2018). In schools, children spend one-third of their day (de Dear et al, 2015). It is important to understand the extent to which people can withstand heat stress, especially in primary schools where children (vulnerable group) congregate in large numbers for class lesson. Children experience a quicker rise in core body temperature (Falk, 2011), and are more vulnerable than adults in extreme heat (Sheffield & Landrigan, 2011). Children lose a relatively greater amount of heat through dry heat dissipation because of their higher body surface area (BSA) to body mass (BM) ration, requiring less evaporation to cool (Inbar, 2004). In most cases, elevated temperatures in summertime are of great concern to vulnerable occupants especially in naturally ventilated buildings (Lomas and Giridharan, 2012).

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Some research works have been carried out in Nigeria to understand the comfort temperature of building occupants (eg; Odim, 2008; Ogbonna & Harris, 2008; Akande & Adebamowo, 2010; Uzuegbunam, 2011; Abiodun, 2014; Adunola & Ajibola, 2016; Adaji, Watkins, & Adler, 2017; Efeoma, 2017; Okafor & Onyegiri, 2019; Alozie, 2020) and a host of others. From their findings, comfort temperatures were found to range from 18-33^{o}C. However, these studies focused on residential buildings, offices, and hostel blocks, and the participants used in the evaluation were all adults. The study conducted by Zhang et al., (2010) suggested that occupants of school buildings located in the temperate region might be at risk of heat and elevated temperatures. In a tropical country like Nigeria, there is a dearth of thermal comfort studies in schools, and at present, there is a scanty of information on the comfort temperature of children in the country. In Nigeria, there is a trend of installing air-conditioning systems in private primary schools, and the trend may extend to the public (government) primary schools that are currently naturally ventilated (NV).

Children from different socioeconomic groups attend public schools in Nigeria and therefore such schools will provide an ideal platform to conduct comfort surveys on children. In addition, the number of occupants in schools is high. Public school buildings do not use cooling systems to provide thermal comfort to the occupants. Therefore, the findings from this research work will be useful to find natural ways to enhance thermal comfort. This study is part of the wider research work that focused on the environmental comfort of schoolchildren. This paper focuses on determining the maximum indoor temperature acceptable by the subjects. Understanding the heat tolerance index and temperatures at which schoolchildren (vulnerable group) can cope in amid the increasing temperature is important. There are extremes at either end of the environmental temperature spectrum, with cold sensation at one end of the spectrum of the 7-point thermal sensation scale, while the warm sensation is at the other end of the spectrum of the same scale. This study intends to focus on the warmer side of the 7-point ASHRAE sensation scale. In this research, field studies were conducted to determine the subject's acceptable maximum temperature in their classrooms categorized according to season and time of day. The findings are compared with ASHRAE Standard 55 and with previous research works conducted in NV classrooms.

The climate chamber experiment used for determining thermal comfort in buildings is not suitable for determining thermal comfort in Naturally Ventilated (NV) buildings (Nicol et al. 2012). The heat balance model, developed by Fanger, overestimates the summer discomfort from running buildings because it failed to take into account human thermal adaptation and other non-thermal issues such as personal and psychological factors (Carlucci et al, 2014). The heat balance model did not consider the outdoor temperature (T_{out}), an important factor in defining comfort and in energy use reduction in buildings. The adaptive model was developed based on the fieldwork that considered an adaptation, personal, and psychological factor. The model relates the indoor comfort temperature with the outdoor temperature. Building occupants in naturally conditioned buildings may not need air-conditioning systems to provide thermal comfort since they can take adaptive actions such as opening windows, doors changing clothes. The influence of occupants in this adaptive action is crucial in the context of thermal comfort. Building occupants influence energy performance in buildings, resulting in the thermal comfort of the occupants. The interactions between the occupant and the immediate environment in a naturally ventilated building are much more dynamic and the occupant's behavioural, physiological and psychological adaptations are wider compared to conditioned buildings (Singh, Mahapatra, & Teller, 2015).

Two popular adaptive models used by thermal comfort researchers are the ASHRAE Standard 55 adaptive model and EN/CEN adaptive model. ASHRAE Standard 55 incorporated an adaptive comfort component in its standard, for designers to embrace passive architectural concepts that encourage the design of buildings that rely on natural ventilation. The common objective of these two models is to deliver comfortable, zero-energy thermal environments. Though both models contain the adaptive component, however they show some differences. The ASHRAE Standard 55 adaptive model is the American version, while the CEN is the European version. De Dear and Brager developed the American version from a fieldwork that covered the entire five continents that make up the world (de Dear & Brager, 1998). Its application is limited to NV buildings where the indoor spaces are regulated, primarily, by the opening and closing of windows by the occupants (ASHRAE, 2017). The European adaptive model limits the application of its limit to buildings without cooling systems. However, both models show some commonality. Both adaptive models consider the outdoor temperature in determining the comfort of indoor spaces. Prevailing mean outdoor temperature above 33.5°C or below 10.0°C are not covered by ASHRAE standard 55 (ASHRAE, 2017; Jindal, 2018), while the EN/CEN adaptive model does not apply in buildings where the mean outdoor temperature is outside the range of 10-30.0^{o}C (CEN, 2007).

Due to the rise in the use of air-conditioning systems in buildings and the negative impact, they have on the environment together with their high rate of energy consumption, adaptive thermal comfort has become an attractive option among researchers in recent years. A significant number of thermal comfort studies carried out in NV educational buildings show that subjects are capable of accepting indoor temperatures beyond the limit specified by the ASHRAE guideline.

ASHRAE guidelines recommend 26.7°C as the upper limit of acceptable temperature during the summer (Hayatu, et al, 2015). A number of thermal comfort studies carried out in NV educational buildings located in different countries show that subjects are capable of accepting indoor temperatures beyond the maximum acceptable value recommended by the international standard. For example, Azali & Hariri (2019) carried out research work in a primary school located in Pari Raja, Malaysia (a tropical country), and found that at the indoor temperature of 30.02°C overwhelming majority (87%) of the subjects accepted the temperature. Other examples are the fieldworks of Jindal (2018), Vien et al (2017), Tari Ahmed (2014), Liang et al (2012), and a host of other works.

2. Methodology

2.1. Study area

In Nigeria, Imo State was chosen as a study area. Imo State has a warm and humid climate. Based on Koppen-Geiger climate classification the state is within the wet and dry or savannah climatic zone. It is between latitude 4° 45′N, 7° 15′N, longitude 6° 50′E, and 7° 25′E, and has two seasons; the rainy season and the dry season. The state is characterized by a high surface air temperature thus providing a challenging design of buildings that can help to moderate the indoor thermal conditions. The wind speed in the warm and humid zone area is generally of low strength (Tammy Amasuomo & Oweikeye Amasuomo, 2016). Providing a comfortable and healthy microclimate is important in educational buildings, in which acceptable temperatures can considerably improve occupants' learning performance (Cognati et al, 2007).

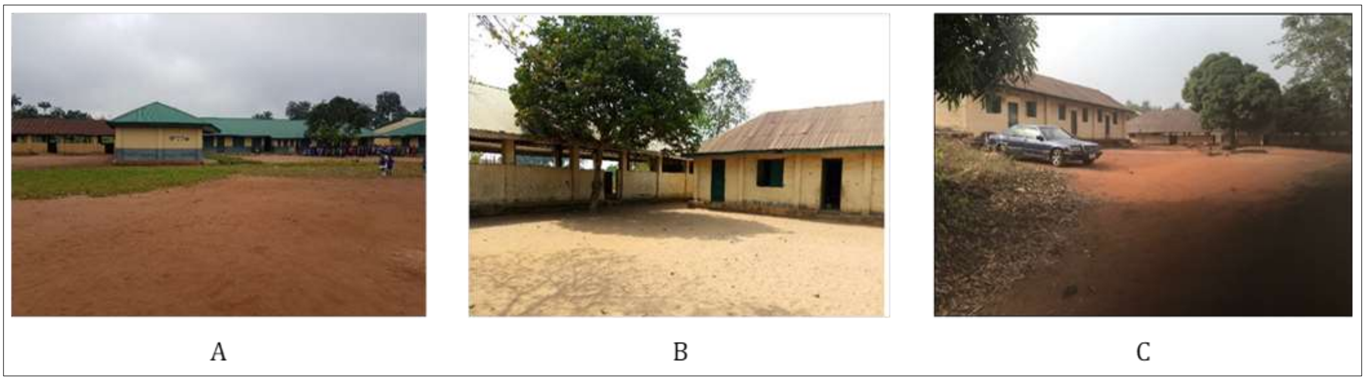

Figure 1 View of the school buildings

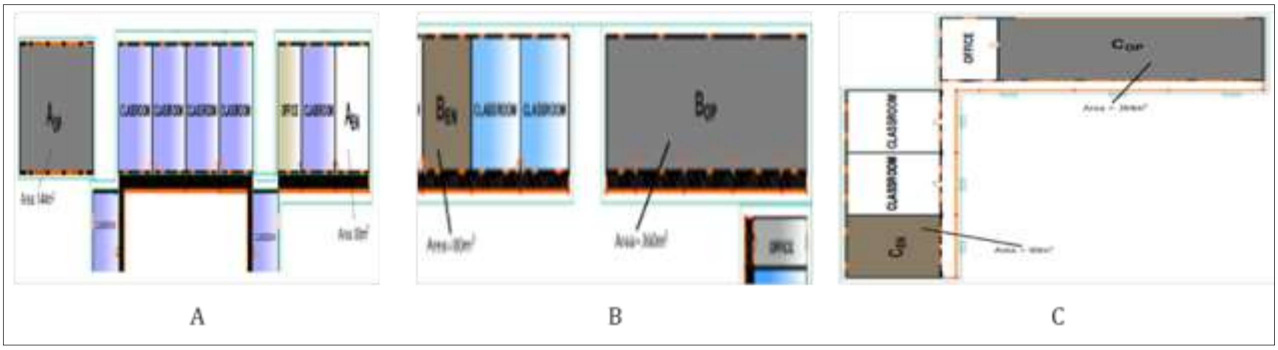

Figure 2 Floor plans of school buildings

A primary school was selected from each of the three senatorial zones that made up Imo State. The schools as shown in Figure 1 are: Premier primary school Umuaka (denoted school A), Central school Ogbaku (denoted school B), and Central school Umuduru (denoted school C). In each of these selected schools, a total of two classrooms (one 'open-space' classroom and one 'enclosed-plan' classroom) buildings were picked for the survey (six classroom buildings in total). All the surveyed classrooms were NV and none of them had any air-conditioning system or fan. The selected classrooms had children within the age range of 7 to 12 years. The number of occupants in each classroom ranged between 25 to 30. Approximately 7060 copies of questionnaires and numerous environmental data were collected from 350 schoolchildren, who were repeatedly surveyed twice a day in two seasons.

Figure 3 Tinytag Ultra 2 (TGU-4500) and Tinytag Plus 2 (TGP-4017)

Table 1 Technical detail of the measuring instruments

Instrument and Make	Measured parameter	Range	Resolution	Accuracy
Tinytag ultra 2 (TGU-4500) logger	Indoor air temperature	-25 to +85°C	±0.01°C	±0.3%
	Indoor relative humidity	0% to 100%	±0.3%.	±1.8% RH
Tinytag Plus 2 (TGP-4017) loggers	Outdoor Temperature	25 to +85 °C	±0.01°C	-
Kestrel 3000 Pocket wind meter	Air velocity	0.30 to 40.0m/s	-	±1.66%

2.2. Data collection and analysis

The research design in this work was fieldwork where longitudinal approach was adopted. In longitudinal surveys, a relatively small number of subjects are polled for their comfort vote repeatedly over an extended period (Humphreys et al., 2015). Because this study involved children, an approval was obtained from the university of Salford ethics committee and from the state ministry of education in Nigeria prior to the commencement of the survey.

In each of the selected schools, the indoor and the outdoor data were collected from the two classrooms simultaneously twice a day. The class lessons were from 7.45 am to 2.45 pm from Monday to Friday. (vii) The first survey of the day was conducted at 9.00 am, one hour after the children have settled to writing or listening to their teachers. The time of the second survey varied from 1.00 pm to 1.45 pm, at least one hour within which the children have settled after physical activities. The survey period was from October 2017 to May 2018, covering rainy season and dry season. Tinytag Ultra 2 (TGU-4500) Gemini loggers measured the indoor thermal variables and indoor relative humidity (RH), while Tinytag plus 2 (TGP-4500) Gemini loggers measured the corresponding outdoor temperature. The outside data logger was well sheltered, avoiding direct sunlight and rainfall while the indoor data loggers were carefully placed at the center of each of the surveyed classrooms. The instruments used for the survey met the prescriptions of ASHRAE 55 (ASHRAE 2017) and ISO 7726 (ISO 2005) Standards. Kestrel 3000 Pocket Wind Meter was used to measure the indoor air velocity.

The questionnaire was based on the comfort question, which focused on the thermal sensation of the subjects. Previous thermal comfort research works on children conducted by Auliciems (1969), de Dear et al (2015), Haddad et al (2017), Xia et al (2020), and a host of other researchers, adopted the same standardized ASHRAE thermal comfort questionnaire used for adults. The reason for adopting a similar question(s) in this survey is to allow for accurate comparison of the findings from this work with previous related works. Thermal comfort questionnaires used in this work adopted a 7-point ASHRAE thermal sensation scale (slightly amended to suite the children) ranging from 'okay to hot' on the right side of the scale and from 'okay to colder' on the left side of the scale (Table 2). The question referred to thermal sensation: *How are you feeling the temperature in the classrooms right now?.* Data collected with the instruments together with the responses in the questionnaire were transferred to Excel spreadsheets,

Table 2 ASHRAE scale for the subjective assessment

ASHRAE 55 standard scale	Cold (-3)	Cool (-2)	Slightly cool (-1)	Neutral (0)	Slightly warm (+1)	Warm (+2)	Hot (+3)
ASHRAE 55 scale for this study	Colder (-3)	Cold (-2)	A bit cold (-1)	Okay (0)	A bit warm (+1)	Warm (+2)	Hot (+3)

3. Results

3.1. Thermal conditions in the classrooms

Table 3 also indicates that 95% of questionnaires returned were validly filled. Table 4 presents the results of the temperature and relative humidity of the surveyed classroom in the three schools visited. The indoor temperature for the combined classrooms all season ranged from 22.5-35.6°C with 29.1°C as a mean value and standard deviation (SD) of 1.7. The outdoor temperature ranged from 23.0-37.4°C with mean value of 29.6°C (SD=1.7). Standard (ASHRAE) 55 does not cover the prevailing mean outdoor temperatures above 33.5°C or below 10°C (Jindal, 2018). The prevailing mean outdoor temperatures calculated from the retrieved data used during the fieldwork were within this range (10-33.5°C). The indoor relative humidity ranged from 24.0-94.2% (SD=12.4) with a mean value of 71.2%. The indoor air velocity was generally low presenting a mean value of 0.19m/s. Figure 4 further illustrates the distribution of indoor operative temperatures (Top) recorded by the data loggers for the combined classrooms all seasons during the survey at occupied school hours. Each bar in the histogram, binned at 2°C, represents the percentage of surveyed samples falling within each range of indoor operative temperature. According to Figure 4, the indoor temperature in the combined classrooms all season within the range between 24 to 34°C was observed, while the range above 34°C was statistically not observed. The histogram, in Figure 4, specifically highlighted that the range of indoor *Top* from 26-30°C prevailed more in the combined classrooms. This range of temperature appeared in approximately 76% of the entire period the survey was carried out. For recorded *Top* below 24°C, only 1% was observed in the combined schools.

Table 3 Summary of Children's Responses

Classroom type	Num of Children (Appro)	Survey date	Season	Administered Questionnaire			
				Expected Number	Actual collected	Valid response	Invalid Response
A_{OP}	25	Oct 12-24 (9days)	Rainy	450	380	370	10
A_{OP}	25	Feb 6-28(17 days)	Dry	850	745	713	32
A_{EN}	30	Oct 12-24 (9days)	Rainy	540	420	411	9
A_{EN}	30	Feb 6-28(17 days)	Dry	850	740	708	32
B_{OP}	25	Oct 25-Nov 3(8days)	Rainy	400	343	330	13
B_{OP}	25	April 2-27(20days)	Dry	1,000	885	817	68
B_{EN}	30	Oct 25-Nov 3(8days)	Rainy	480	415	404	11
B_{EN}	30	April 2-27(20days)	Dry	1,200	961	880	81
C_{OP}	25	May 9-29(15days)	Rainy	750	620	595	25
C_{OP}	25	Jan 15-31(13days)	Dry	650	520	508	12
C_{EN}	30	May 9-29(15 days)	Rainy	900	785	716	69
C_{EN}	30	Jan 15-31 (13 days)	Dry	780	610	598	12
Total	330	164 visits		8850	7424	7050 (95%)	374(5%)

Table 4 Thermal conditions and subjects responses in the surveyed classrooms

Thermal conditions	Mean	Standard Deviation (SD)	Min	Max
Air temperature (°C)	29.1	1.7	22.5	35.6
Indoor operative temperature(°C)	29.1	1.8	22.3	35.7
Outdoor temperature (°C)	29.6	1.7	23.0	37.4
Indoor Relative humidity (%)	71.2	12.4	24.0	94.2
Indoor air velocity (m/s)	0.19	-	0.12	0.30

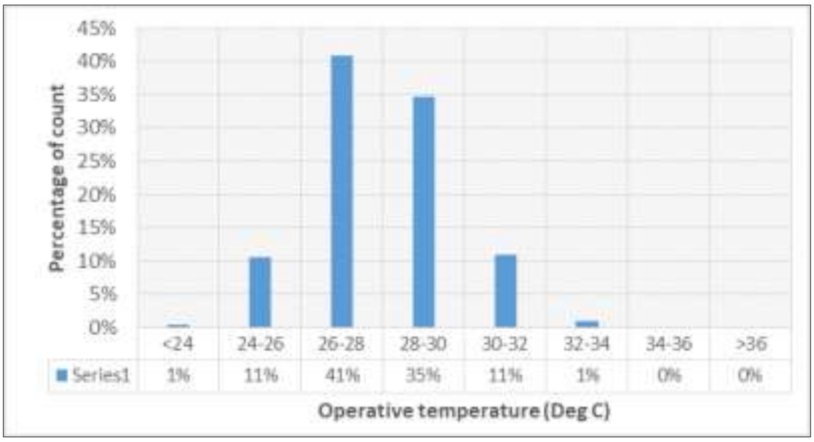

Figure 4 Histogram of T_{OP} at occupied time in combined classrooms all season

An acceptable temperature of the studied school children can be determined using the ASHRAE adaptive comfort model that sets the comfort zone between thermal sensation range from -0.85 to +0.85 at 80% satisfaction (ASHRAE 55, 2017). To find the acceptable range of temperatures at 80% satisfaction, operative temperatures were calculated from the linear equations (shown in Table 4) for the mean TSV= ±0.85. However, this study focuses on the upper limit of the comfort zone which corresponds to TSV = +0.85. Table 5 summarizes the result of the regression analysis of children's mean thermal sensation votes against the mean indoor operative temperatures and the maximum acceptable temperature according to the season, and according to time of the day. The result shows that the maximum (max) indoor temperature (upper limit) accepted by the studied children for the combined classrooms all seasons was 31.6°C at 80% satisfaction (p-<0.005). In the morning hours, the acceptable max indoor temperature was 31.2°C while in the afternoon period it was 32.2°C. During the rainy season, the acceptable limit was up to 31.4°C, while during the dry season it was 30.2°C. Further statistical analysis indicates that the models shown in Figure 5 can only explain 51% of the relationship between the total thermal sensation votes and indoor *Top* for the combined classrooms all season. In addition, 56% and 46% of the relationship during the morning hours and afternoon hours respectively can be explained. For the rainy season and dry season, only 50% and 30%, respectively can be explained. However, because the *p* values in all the models are less than 0.005, the relationships are statistically significant.

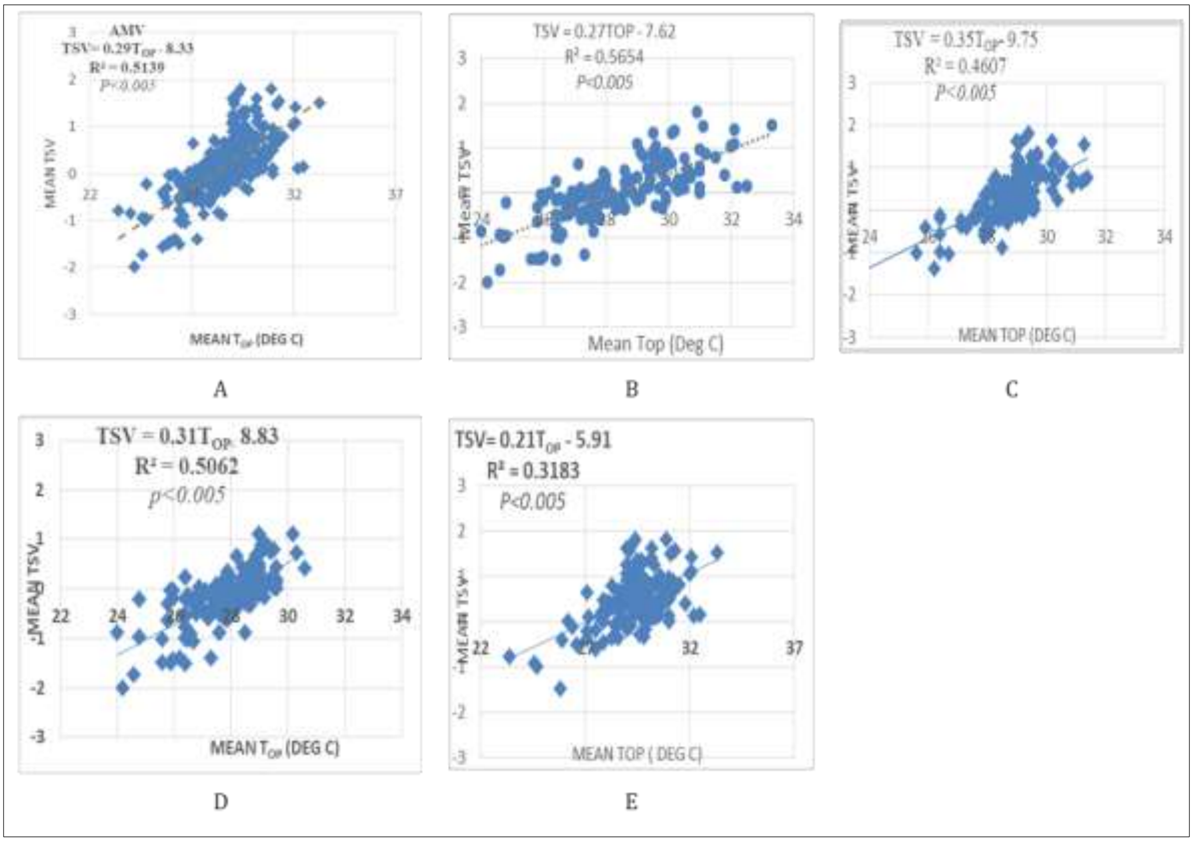

Figure 5 Regression between indoor Top and thermal sensation with lines of 95% confidence level for (a) combined classrooms, (b) rainy season, (c) dry season, (d) morning hours, (e) afternoon hours

Table 5 Maximum comfort temperature and mean values of outdoor temperature

	Equation	**Maximum Comfort temperature (°C) (AMV+0.85: 80%)**	**Mean outdoor temperature (°C)**
All classrooms (a)	$TSV=0.29T_{op}$- 8.33	31.6	29.9
All classroom rainy season (b)	$TSV=0.27T_{op}$-7.62	31.4	29.7
All classrooms dry season (c)	$TSV=0.35T_{op}$-9.75	30.2	29.9
All morning (d)	TSV=031 T_{op}-8.83	31.2	28.5
All afternoon (e)	$TSV=0.21T_{op}$-5.91	32.2	30.1

4. Discussion

4.1. Maximum comfort temperature

An acceptable indoor temperature of subjects in a building can be determined using the ASHRAE adaptive comfort model that sets the comfort zone between thermal sensation range from -0.85 to +0.85 at 80% satisfaction (ASHRAE 55, 2017). To determine the acceptable temperature, the mean TSV of the studied children plotted against the mean indoor operative temperature (*Top*) produced an upper limit (maximum) acceptable temperature of 31.6°C at 80% satisfaction ($p<0.005$) for the combined classrooms all seasons. The adaptive thermal comfort model suggests that building occupants do adapt to temperatures that prevailed more having got familiar with them. From the result of this study, the upper limit acceptable temperature (31.6°C) is very close to the upper limit of temperature the studied children encountered daily 30°C (range 26-30°C) during their class lesson, The max acceptable temperature is also close to the mean indoor operative temperature (29.1°C) observed during the survey. The max acceptable indoor temperature in the morning hours and afternoon hours were 31.2°C and 32.2°C, respectively. The max acceptable temperature during the rainy season was 31.4°C, while during the dry season it was 30.2°C. The result suggests that the heat tolerance of the studied schoolchildren is quite high.

4.2. Comparing Acceptable Temperature with Adaptive Comfort Model

The present study on an acceptable range of temperatures of the children categorized according to time of day and season indicated that the subjects accepted warmer conditions than the one predicted by ASHRAE adaptive comfort model. The studied subjects accepted temperature that was 4.9K warmer than the upper limit recommended by the ASHRAE standard 55. Furthermore, according to time of day the upper limit of the comfort range during the morning hours afternoon hours were by 4.5k and 5.5k, respectively warmer than the upper limit of the international standard. In addition, according to season the upper limits were 4.7K higher than the standard during the rainy season and 3.5K higher during the dry season. The results further suggested that irrespective of time of day or season the studied schoolchildren in the warm and humid climate in Nigeria have a higher tolerance to indoor temperatures than the standard suggested. This is because most of the subjects accepted the existing thermal conditions in the classrooms, which exceeded the comfort range recommended by ASHRAE Standard 55 for summertime. The result is consistent with some previous studies that came out with similar findings of the comfort temperatures outside the ASHRAE recommended acceptable range (e.g. Azali & Hariri, 2019; Jindal, 2018; Wong & Khoo, 2003).

4.3. Previous works

The finding from this work is similar to those found in works conducted in the tropics and subtropical zones show a high level of adaptation and acclimatization of the students to the climate of tropics. The maximum comfort temperature found in this study were within the range 30-32°C, irrespective of the season or time of day the survey was carried out. The finding from this work is comparable with that found in related work conducted in tropics and subtropical zones, indicating a high level of adaptation and acclimatization of people living in the tropical zones to temperatures. For the studies in school settings located in composite climates of India, 33.7°C was found as the maximum comfort temperature in the research work of Jindal (2018) and 32.0°C by that of Singh et al (2018). For schools located in the tropical zone, the upper limit of the comfort temperatures found was; 30.6°C in Mexico by Cetz & Azpeitia (2018), 33.0°C in Vietnam by Vi et al (2017), 31.5°C in Kharagpur India by Mishra & Ramgopal (2015), 29.5°C in upper Egypt by Saleem and a host of other studies from the tropical zone. In the sub-tropical zone, an upper limit of 30.0°C was produced in a study conducted in a school in Taiwan by Hwang et al (2009), while in a hot dry and warm humid climate in Dhaka Bangladesh 32.6°C was found as the maximum comfort temperature by Tari &Ahmed (2014).

In all these studies, the subjects demonstrated considerable adaptability to a high indoor temperature at 80% occupant satisfaction. The high acceptability is due to adaptive measures employed by the schoolchildren. Such measures were; behavioural adaptation (which involved the opening of windows to allow for more airflow into the classrooms), physiological adaptive measure (adapting to the local weather they were used to), and psychological adaptive measures (thermal experience and expectation). However, the acceptable upper limit found in a study conducted in Doula Cameroon (27.8°C) was significantly lower than the values found in this study. The main reason for the difference is connected to the difference in prevailing temperature in this study area and that of Doula. While the average temperature in this study area varied between 28 to 29°C that of Doula varied between 23.3 to 26.8°C.

5. Conclusion

The studied schoolchildren can accept temperatures above 30°C by employing adaptive measures. Children spend a considerable part of their day in classrooms and the indoor environment they encounter during this period affects their health and the development of their cognitive skills. This study found that children who use NV classroom buildings located in a tropical region could accept an indoor temperature that is higher than the upper limit of ASHRAE comfort temperature. The government is the provider of school education in Nigeria and still builds the bulk of primary schools. Designers of schools in the tropics must incorporate passive features that will help schoolchildren and their teachers to adapt to indoor classroom spaces.

Compliance with ethical standards

Disclosure of conflict of interest

The author states that there is no conflict of interest.

References

[1] Abiodun O 2014 Thermal Comfort and Occupant Behaviour in a Naturally Ventilated Hostel in Warm-Humid Climate of Ile-Ife, Nigeria: Field Study Report During Hot Season Global Journal of Human-Social Science: B. *Geography, Geo-Sciences, Environmental Disaster Management*, 14(4)

[2] Adaji M et al 2017 Indoor Thermal Comfort for Residential Buildings in the Hot-humid climate of Nigeria during the Dry Season. Design to Thrive. *Plea* 2017. 949-956.

[3] Adunola A and Ajibola K 2016 Factors Significant to Thermal Comfort Within Residential Neighborhoods of Ibadan Metropolis and Preferences in Adult Residents' Use of Spaces. *SAGE Open*, 6(1).

[4] Akande O and Adebamowo M 2010 Indoor Thermal Comfort for Residential Buildings in Hot- Dry Climate of Nigeria, In *adaptation to change*: New thinking on comfort. Cumberland Lodge, Windsor, London, UK*: Network for Comfort and Energy use in Buildings.* 9-11

[5] Alozie G 2020 Comparative Study of Roof-Heat in Buildings with Concrete Facia and Buildings with exposed Eaves in Umuahia Abia State Nigeria, *Middle East Journal of scientific research;* 28(2), 129-131.

[6] Anderson et al 2013 Heat-related emergency hospitalizations for respiratory diseases in the Medicare Population. *Am J Respir Crit Care Med*. 2013. 187(10);1098-1103

[7] ASHRAE A 2017 Standard 55-2017. *Thermal Environmental Conditions for Human Occupancy*.

[8] Auliciems A 1969 Thermal requirements of Secondary School Children in Winter. *Epidemiology & Infection*, *67*(1), 59–65.

[9] Azali W and Hariri A 2019 Thermal Comfort Study in Naturally Ventilated School Classrooms in Pari Raja, Batu Pahat. *Journal of safety, Health and Engronomics*; 1(2); 1-6.

[10] Calucci S et al 2014 Statistical Analysis of the Ranking Capability of Long-Term Thermal Discomfort Indices and their Adoption in Optimization Processes to Support Building Design, *Building Env* (75), 114-131.

[11] CEN 2007. 15251: 2007. Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics. *Brussels, Belgium*.

[12] Cetz M and Azpeitia G 2018 Thermal Comfort in Classrooms in Mexico's Hot and Humid Climate. *Rethinking comfort* 2018. Windsor conference 12 -15th April 2018

[13] Corgnati S et al 2007 Perception of the Thermal Environment in High School and University Classrooms: Subjective Preferences and Thermal Comfort. *Building and Environment*, 42(2), 951– 959..

[14] de Dear, RJ et al 2015 Adaptive thermal comfort in Australian School Classrooms. *Building Research & Information*; 43(3): 383-398

[15] de Dear R and Brager G 1998 Developing an Adaptive Model of Thermal Comfort and Preference. *Proceedings of the 1998 ASHRAE winter Meeting*, San Francisco. CA, USA: ASHRAE; 1998, 145-67.

[16] Efeoma M 2016 The Influence of Clothing on Adaptive Thermal Comfort: A Study of the Thermal Comfort of Office Workers in Hot Humid Conditions in Enugu, Nigeria, PhD Thesis

[17] University of Edinburgh, UK.

[18] Falk B and Dotan R 2011 Temperature Regulation and Elite Young Athletes, *Med Sport Sci*. (56), 126-149.

[19] Haddad S et al 2017 Revisiting Thermal Comfort Models in Iranian Classrooms During the Warm Season. *Building Research & Information*, *45*(4), 457–473.

[20] Hayatu I et al 2015 Asseasment of Thermal Comfort in Hot and Dry Season (A case study of 4 Theatres at Bayero University Kano).

[21] Hoshiko S et al 2006 Simple Method for Estimating Excess Mortality due to Heat Waves, as

[22] Applied to the 2006 California Heat Wave*. Int' J' of Public Health.* 2010. 55(2): 133-137.

[23] Humphreys, M., Nicol, F., & Roaf, S. (2015). *Adaptive thermal comfort: foundations and analysis*. Routledge.

[24] Hwang R. et al 2009 Investigating the Adaptive Model of Thermal Comfort for Naturally Ventilated School Buildings in Taiwan. *International Journal of Biometeorology*, 53(2), 189–200

[25] Inbar O et al 2004 Comparison of Thermoregulatory Respondses for Exercise in Dry Heat among Prepubertal Boys, Young Adults and older Mates. *Experimental physiology*, 89 (6), 691-700.

[26] Iso E 2005 7730: 2005. *Ergonomics of the Thermal Environment-Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria*.

[27] Jindal, A 2018 Thermal Comfort Study in Naturally Ventilated School Classrooms in Composite Climate of India. *Building and Environment*, (142), 34–46.

[28] Koop L and Tadi P 2019 Physiology, Heat loss (convention, evaporation, radiation). StatPearls Publishing LLC, (2019), 24.

[29] Liang H et al 2012 Linking occupants' Thermal Perception and Building Thermal Performance in Naturally Ventilated School Buildings. *Applied Energy*, (94), 355–363.

[30] Lomas K and Girdharan R 2012 Thermal Comfort Standards, Measured Internal Temperatures and Thermal Resilience to Climate Change of Free-running Buildings: A case-study of Hospital Ward, *Building and Env*, (55); 57-72.

[31] Meehi G and Tebaldi C 2004 More Intense, more Frequent, and longer lasting Heat Waves in the 21st century, *science,* 5686 (305), 994-997.

[32] Mishra A and Ramgopal M 2015 A Thermal Comfort Field Study of Naturally Ventilated Classrooms In Kharagpur, India. *Building and Environment*, (92), 396–406.

[33] Munonye C C & Ji Y 2021 Evaluating the perception of thermal environment in naturally ventilated schools in a warm and humid climate in Nigeria. *Building Serv. Eng. Res. Technol*. 2021, Vol. 42(1) 5–25

[34] Nicol F et al 2012 *Adaptive Thermal Comfort: Principles And Practice*. Routledge

[35] Odim O 2008 Experimental Studies of Comfort Levels of East-West And North-South Solar-Oriented Buildings in a Warm-Humid Climate. *Architectural Science Review*, 51(4), 403–406

[36] 0gbonna A and Harris D 2008 Thermal Comfort in Sub-Saharan Africa: Field Study Report in Jos-Nigeria. *Applied Energy*, 85(1), 1–11.

[37] Okafor M and Onyegiri I 2019 Relating Forms and Materials of Traditional and Contemporary Building Types to Indoor and Outdoor Air Temperatures for Sustainable Development in Okigwe, Nigeria. *Revista Romana de Inginerie Civila*, 10(3), 290–295.

[38] Ricardo F and Natalia G 2015 Review of Human Thermal Comfort in the Built Environment. Roberto Lamberts. *Energy and Buildings.* 2015. (105): 178-205.

[39] Sheffield P and Landrigan P 2011 Global Climate Change and Children's Health Threats And Strategies for Prevention, *Enviro, Health Sciences Perspective*, (119), 291-298.

[40] Singh M et al 2015 Development Of Thermal Comfort Models For Various Climatic Zones of North- East India. *Sustainable Cities and Society*, (14), 133–145.

[41] Singh M et al 2018 Status of Thermal Comfort in Naturally Ventilated Classrooms During the Summer Season in the Composite Climate of India. *Building and Environment*, (128), 287-304.

[42] Tammy Amasuomo, T., & Oweikeye Amasuomo, J. (2016). Perceived Thermal Discomfort and Stress Behaviours Affecting Students' Learning in Lecture Theatres in the Humid Tropics. *Buildings (2075-5309)*, *6*(2).

[43] Tari T and Ahmed 2014 Perception of Indoor Temperature of Naturally Ventilated Classroom Environments during Warm Periods in a Tropical City. Plea 30th inter conference 2014.

[44] Uzuegbunam F 2011 Towards a Design Strategy For Effective Passive Ventilation Of Student Hostels in Hot-Humid Tropical Environment Of Enugu Campus, University Of Nigeria. *PhD Theses*.

[45] Vi Le T et al 2017 Children Thermal Comfort in Primary Schools in Ho Chi Minh City in Vietnam, *33rd PLEA 2007 conference, Edinburgh*, Scotland 2nd – 5th July, 2017.

[46] Wong N and Khoo S 2003 Thermal Comfort In Classrooms In The Tropics. *Energy and Buildings*, 35(4), 337–351.

[47] Xia Y and 2020 Experimental and Numerical Studies on Indoor Thermal Comfort in Fluid Flow; A Case Study on Primary School Classrooms; *Case studies in thermal engineering*. 19.

[48] Zhang Y et al 2010 Thermal Comfort In Naturally Ventilated Buildings in Hot-Humid Area Of China,*Building and Env*, 45 (11), 2562-2570.