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Field Study of Thermal Comfort and Core Body Temperature Between Males and Females in Kaduna, Nigeria.

Charles Yakubu Makun
Department of Architecture, Federal University of Technology Minna, Nigeria[1].

Abstract

Thermal comfort is a condition in which a person or persons expresses satisfaction with the thermal environment (ASRAE,2004). Two concerns lead to the present study. First, research concerning whether there is difference in thermal comfort of males and females has evoked numerous research. However the results have been inconsistent,with some results showing that there is a significant difference between thermal comfort of males and females while some did not find any significant difference.Second, literature review prior to this study sugest that most of the studies related to differences in thermal comfort between males and females have been mostly carried out in cold and temperate climates.Thus, motivated by the concerns mentioned here, a study into gender difference in the thermal comfort was conducted. The study involved literature review into gender difference in thermal comfort. Following the literature review, a field study was conducted during a school day in November 2021 using 80 samples(15-17years), they are from a private secondary school in kaduna. At the field study, the thermal comfort and core body temperature of the subjects were measured at six indoor air temperature levels (27.29, 29.01.30.83, 32.8,34.66,35.19°C). As well, during the field study, the samples dressed in similar clothing(clo) insulation values and they performed similar activities corresponding to 1.0 met. Analysis of data from the field study using Mann-Whitney U test and the independent sample t-test showed that there is no significant difference between the thermal comfort and core body temperture of males and females.In short, the result from this study suggests that there is no signficant gender difference in thermal comfort and core body temperature provided that the males and females have similar *clo* and *met* values in the same environment.The practical implication and limitation of this study has been disscussed.

Key words: Thermal comfort, indoor air temperature, Gender difference, core body temperature, Male, Female.

1. Introduction

The key concern of the author of this present paper from a wide literature review (Karjalainen, 2011; Wang et al., 2018) are two: Firstly, results from previous research showing whether the thermal comfort of males significantly differ from females have been inconsitent, results such as significant, weak sigficance and no significant gender difference have been reported by various authors. Secondly, research into whether the thermal comfort of males differ from that of females have been mostly conducted in climatic chambers as well as in cold and temperate climates with little aplicable to tropical climates and non applicable to the tropical climate of Nigeria.Although some Authors have have conducted thermal comfort studies in Nigeria, however, they did report, whether there is gender difference in the comfort temperatures identified from their research (Ogbona & Haris, 2007 ; Akande & Adebamowo, 2010; Jimoh & Demenongu-Demshakwa, 2020)

Therefore, motivated by the two concerns put above, this study aims to investigate whether the thermal comfort of males differs from that of females as aresult of indoor air temperature in a tropical climate. Kaduna in Nigeria was used as geographic context for this study, this is because the permision and logistic of gathering data for this present study was readily available from a private school in Kaduna. Kaduna is the capital city of Kaduna state, the state is located in the North-Central part of Nigeria. In addition to the aim of this study, the objective of this study is to examine gender difference in core body temperature. The results of from this study may contribute the findings of other researches as regards whether gender difference exist in thermal comfort As well,

*Authorforcorrespondence: charles.makun@futminna.edu.ng

from results in this study, it may be possible for designers and policy makers to predict which gender (male or female) to is to considred most when specifying indoor thermal comfort conditions for school buildings in the tropical climate of Nigeria.

2. literature review

Wyon et al. (1972) conducted a climatic chamber study with the aim of proposing a new method of measuring thermal comfort and discomfort via the use of dial voting scale. The study was conducted with 72 healthy danish high-school pupils of approximately 15- 17 years old (36 male and 36 females, they were dressed in 0.7 clo). The subjects were exposed to temperature changes between 20 and 29 ^{0}C in goups of 4 while they perform mental tasks. Their thermal sensation was measured on a dial voting apparatus. The voting appratus had five scales (i.e. much too cold, cold, comfortable, hot and much too hot). The result from the climatic chamber study of Wyon et al.(1972) shows that the male subjects were significantly warmer than the female subjects.

Fanger et al. (1974) carried, out a climatic chamber study with 16 subjects dressed in 0.6 clo. The study compared the physiological and pyschological difference in the thermal comfort of males and females. Their result shows that there is no significant difference in the preferred ambient temperature of the male and female subjects. However, the skin temperature and metabolic rate of the female subjects were sligthly lower than those of the males.

Bashir & Ramsey (1981) in a climatic chamber study compared the thermal sensation and productivity of 31 male and 15 female American subjects, the clothing insulation value of the subjects is 0.6clo, they were exposed to four temperature levels in the climatic chamber (23.3,32.2,37.8 and 43.3 ^{0}C). During the experiment the subjects performed perceptual –motor tasks at the same time they were requested to complete a questionaire about their thermal sensation and some subjective variables (i.e. drowisines, boredom and fatigue).Bashir & Ramsey (1981) found that the preferred temperature of male (22^{0}C) is significantly lower than those of females (25^{0}C).Their conclusion reads that; (1) females could be more thermally dissatisfied in comparison to males (2) females have a higher tendency to exhibit symptoms of boredom and drowsinesss than males at high and low temperature extremes.

Again, results from two independent similar climatic chamber studies conducted by De dear et al. (1991) and Grivel & Candas (1991) suggest that there is no signficant difference in the thermal preference of males and females as result of indoor air temperature. de Dear et al. (1991) compared the thermal preference of a sample of college-age Singaporeans (16males and 16 females), they dressed in 0.6 clo. Gravel and Candas (1991) compared the ambient temperature preferred by 48 European subjects dressed in 0.6 clo.

Lan et al. (2008) studied gender difference through two laboratory experiments with Chinese college age subjects, they were dressed in clothing insulation value of 0.8clo. One of the relevant findings from the study of Lan et al. (2008) is that, females can be slithgly more dissatified than males at cooler conditions, Parsons (2002) found similar result from a climatic chamber study. Parsons (2002) found that, given the same activity and clothing insulation levels, there is only a small difference between the thermal comfort of male and female at neutral and warm conditions, however females could be more thermally dissatisfied at cooler conditions (18.5^{0}C). Similarly, females have been found to be more thermally dissatified than males at cooler temperatures of about 18^{0}C (Tiller et al., 2010).

Lastly, a climatic chamber study was performed with Chinese college- age subjects by Liu et al. (2011), the subjects included 12 males and 10 females dressed in vest and shorts (0.3 clo). The subjects were exposed to four temperature levels of 21,24,26 and 29^{0}C during the experiment. The result from the study of Liu et al. (2011) shows that the mean skin temperature and thermal sensation of females was lower than those of males, however there was no statistically significant difference between the mean skin temperature and thermal sensation of the male and female subjects.

From a field study conducted in Sanfrancisco Schiller et al. (1988) found out that the there is no signicant difference in the neutral and preffered temperature of the male and female subjects. The field survey was conducted during summer and winter in some office buildings with 187 female and 117male subjects aged 20-50.

Seemingly, Karyono (2000) reported that the neutral temperature and comfort ranges between males and

females was negligible and not statistically significant. The study of Karyono (2002) was conducted at Indonasia in some office buildings with 596 subjects of age 19-53. Again, from a Hong Kong field study, Wong et al. (2009) found similar result to Karyono (2002),they found that when it comes to thermal comfort, there may be no significant gender (male and female) difference with respect to predicted mean vote and neutral temperatures.

Furthermore, Becker & Paciuk (2009) found that the difference in the thermal comfort votes of males and females do not significantly differ, this result shows that the thermal comfort of males does not significantly differ from those of females given the same activity(met) and clothing insulation (clo) levels. The field study of Backer & Paciuk (2009) was conducted with approximately 394 residential buildings in Haifa, Isreal. There are other field studies which the results shows that there is no significant difference in thermal comfort of males and females (e.g. de Dear & Fountain 1994; Melikov et al., 2005; Kuchen & Fisk, 2009; Choi et al., 2010; Peng, 2010), these studies were conducted in Australia, Denmark,Germnay,USA and China respectively.

In contrast to the non significant gender difference from field studies reported above, significant gender difference has been reported from several field studies. Federspiel (1998) conducted a study with some commercial buildings in the USA, The author observed that the female subjects were significantly cooler than the male subjects. Significant difference has also been reported from a field study conducted in Japan (Nakano et al.,2002), the author found out that there is a significant difference between the neutral temperature of Japanese male and female.

Another, field study conducted with approximately 3094 respondents in Finland observed that in comparison to the male subjects, the female subjects were less uncomfortable with the indoor temperature of their rooms at relatively hot and cold (extreme) temperatures (Karjalainen 2007). Furthermore, a higher percentage of female have been reported to be thermally dissatified than males in the classrooms of seven universities in Taiwan (Hwang et al.,2006). Similar result to the result of Hwang et al, (2006) was reported by Krauchi et al, (2008) ,they reported that a higher percentage (31%) of females have been documeted to express thermal dissatisfaction than the male subjects (7%) at cold conditions. Lastly, part of the findings from a field study in Zambia showed that females can be more thermally dissatisfied than males at relative low temperatures (Sharples & Malama,1997).

Nevertheless there are thermal comfort studies that were conducted in residential and office buildings in Nigeria, however, their results focused mainly on determining thermal comfort conditions indoors with no results showing gender differences in thermal comfort (Ogbona and Haris, 2007 ; Akande & Adebamowo, 2010; Adaji et al., 2017; Jimoh & Demenongu-Demshakwa, 2020). For instance, Ogbona & Haris (2007) found that the preffered temperature in residential buildings in Jos,Nigeria is about 26^{0}C. Jimoh & Demenongu-Demshakwa (2020) found that the neutral temperature for naturally ventlated office in Jos is 29.4^{0}C.

To conclude, the literature review presented in the past paragraphs shows that when it comes to thermal comfort, the relationship between indoor air temperature and gender have yielded mixed results. However one trend seems to be more prominent from the results in the review.The trend is that females have been documented to be more thermally (uncomfortable) dissatified at relatively cold condtions. Also, most of the studies in the review concerning gender difference in thermal comfort have been conducted in cold and temperate climates with little in subtropics and very little in the tropics. Lastly, the review shows that studies concerning thermal comfort in Nigeria focused mainly on determining thermal comfort conditions and not differences in the thermal comfort conditions between male and female.

Thus the key question from the literature review in this section is that, is there any significant difference in thermal comfort between males and females as a result of indoor air temperature when it comes to people who live in the tropical climate of Nigeria?

3. Methods

3.1 Setting

The field study was conducted in two classrooms on the second floor of a private secondary school in Kaduna after obtaining permission from the proprietor. The two classrooms are similar in size, facilities and orientation (longest sides on East-West axis). Furthermore, the classrooms are naturally ventilated as such, no heating and cooling equipment

was observed. Each classroom is approximately 8x9M ($72M^2$). The wall of classrooms are built with 225mm sandcrete hollow blocks and internally finished with plaster and white paint.The floors are made from reinforced concrete and finished with terrazo, the roof is covered with aluminium sheets, the ceilings are mineral fibre suspended ceiling.The frame of the windows are made from aluminium sections and the sahes are plain glass. The rationale behind why one school was used for this field study is that, many of the schools approached for this study believed that the results from this study was to promote gender difference in schools.Another reason why one school was used for this study is that many schools were not ready to allow vistors into their schools due to the ever increasing rate of kidnapping and terrorism in Kaduna as at the time of this study.

3.2 Subjects/sample size

The subjects have ethnic background as Nigerians, they are Seniour Secondary level 3 students (SS3 students) Seniour Seconday level 3 students corresponds to year 12 students of a high school in the UK . Out of the 123 SS3 students in the school as at the time of study, 80 subjects (40 males and 40 females 15-17 year- old) were randonly selected to participate in the field study.They participated at the field survey following an informed consent. The males and females dressed in light clothing 0.50 and 0.49 clo respectively, these clo values(0.50 and 0.49) corresponds with a person wearing light clothing (ASHRAE, 2004).As well, their activity level was estimated to be 1.0 met, this met value corresponds to classroom activity (ASHRAE, 2004). Furthermore, the subjects were requested to have adequate rest and abstain from,smoking, alcohol and caffeinated drinks prior to the day of the field study, smilar request was employed in a similar study by Li lan et al. (2008).

3.3 measurment of thermal comfort and core body temperature

The seven-point ASHRAE (2004) thermal sensation voting scale was used to measure the thermal comfort of the subjects, Table 1. The voting scale was presented in the form of a questionaire. The questionaire also requested the subjects to provide some additional information (age,sex ethnic backgroung, time of survey and some health status. Furthermore, the core body temperature of the subjects was measured at the field survey, this was done by the use of a hand held digital thermometer (BEURER FT 85 Digital forehead Thermometer).

Table 1: ASHRAE (2004) Sensation scale: kindly rate how hot or cold you are right now ,please tick only one response in the table.

cold	cool	Slightly cool	Neutral	Slightly warm	warm	hot
-3	-2	-1	0	1	2	3

3.4 measurments of indoor variables

Physical measurements of some indoor environmental variables were taken, see Table 2.

Table 2: Description of some measuring equipment used in the field study

Variable	Type and description of key features	Use
Air temperature and Relative Humidity	Exitech 42280 Temperature and humidity data logger. Measures temperature from -20 to 70°C with an accuracy of ± 0.6°C. Measures humidity from. 0 to 100% with an accurracy of ±3%	Measurment of indoor air temperature and Relative humidity
Anemometer	Testo 425 measures wind air velocity in the range of 0 to +20m/s	Measurment of air velocity

3.5 Measurment protocol

The field study was conducted simultaneusly in two classrooms during a school day in November 2021. Each classroom had 40 participants in a balanced order(20 males and 20 females).The field study was conducted with the author of this present work and four assistants. The steps used to collect data at the field study is presented below.

1) **Introduction.** A day before the field study was conducted, the reseacher and his team presented the purpose and process of the field study.
2) **Positioning of equipment**. The equipment used for measuring the indoor environmental variables were positioned on a platform of 1.1M high at the centre of one of the two classrooms used for the field survey. This was followed by testing the funtionality of the equipment. This was done between 06.30 am – 07.30am on the day of the field survey.
3) **Positioning of students and distribution of survey questionaire.** 7.30am -8am, the students(subjects) in the classrooms were positioned on their desks and a brief of the field survey protocol was recasted. Also, the survey questionaire was distributed, they were immidiately requested to write down some vitals on the questionaire (i.e., expermental code name of subjects, time of the day/date, code name of classroom)
4) **Simultanous measurment of variables.** From 8am -2 pm (6hours), subjects in the two classrooms used for the field study were requested to record their thermal comfort and core body temperature on an hourly basis .At the same time the indoor variables were rocorded on a hourly basis from one of the classroom .The core body temperature of each subject was measured by reseach assistants and the value was recorded by the subject on the questioniare provided for the study.Again,during the hourly measurment of the aformentioned variables, subjects were allowed to perform various academic task that corresponds to the classwork of the day, the tasks include, reading,copying notes and completing previous assigments. Lastly, during the measurments of variable, subjects were provided water and snacks, they were also allowed to take a 10 minutes break on request.
5) **Exit.** At the end of the field survey, the questionaires were retreived from the subjects, this was followed by a vote of thanks

3.6 Data analysis

SPSS version 24 was the soft ware used to analyse the data in this present study. Mann-Whitney U test was used to compute gender difference in thermal comfort and the independent t-test was utilised in computing gender difference in core body temperature of the subjects. The statistical sigficance was put at 95% ($p \leq 0.05$)

4. Results

4. 1 Descriptive data of the subjects

The number of subjects that participated in this study is 80 (40 males and 40 females). The subjects dressed oin similar clothing insulation value of 0.5 clo males and 0.49 clo females. Thus, the difference between the clothing insulation values of male and female in this study is 0.01, this value (0.01) was considered in this study as negligible. However, the subjects were performing similar activities (school task) during the field study, thus it was deduced that the met value of the subjects is 1.0 met (ASHRAE, 2004).

4. 2 Indoor environmental variables

Find in Table 3 the indoor environmental variables in the classrooms during the field study

Table 3: Indoor environmental variables measured at the field study.

Time	Indoor air temperature (^{0}C)	Relative humidity (%)	Air velocity(m/s)
9am	27.29	45.62	0.35
10am	29.01	42.9	0.32
11am	30.83	40.14	0.26
12pm	32.8	35.24	0.15
1.pm	34.66	31.1	0.13
2pm	35.19	30.57	0.11

4. 3 Thermal comfort

Mann-Whitney U test was used to compute gender difference in thermal comfort in respect of the subjects used for this study, Table 4 summarise the result of gender difference in thermal comfort at the six different indoor temperature levels utilised for this study. The result in Table 4 shows that in all the six temperature levels when the thermal comfort of the subjects were measured, there is no significant difference between the mean rank of the thermal sensation votes of the male and female subjects. Although, the mean rank of the thermal sensation votes of females was slighthly higher those of males in all the six temperature levels. In sum, the results in Table 3 shows that this study found no significant difference in the thermal comfort of males and females, (thermal sensation vote is measure of measuring thermal comfort.

Furthermore, descritive analysis of the Predicted Mean Vote accross the six temperature levels is presented in Table 5.The Table shows that there is a linear relationship between temperature and thermal discomfort .This means as the indoor air temperature increases, thermal discomfort also increases.

Lastly from Table 5, it can be seen that the subjects were thermally comfortable between 27.29 and 30.83^{0}C,this is because the mean thermal sensation vote of the subjects is between 0.5 and 1, mean thermal votes in range 0.5-1 on the ASHRAE (2004) thermal sensation scale shows that persons are thermally comfortable. Incontrast,the subjects were thermally dissatisfied between 32.8 and 35.19^{0}C. This because the mean votes of the subjects is between 1.6 and 2.7, mean votes in this range (1.6 and 2.7) suggest that the subjects are warm and hot (ASHRAE ,2004).

Table 4: Result of Mann-Whitney U test showing gender difference in thermal comfort.

Indoor air temperature^{0}C	Mean rank of Predicted Mean Votes of males (PMV)	Mean rank of Predicted Mean Votes of females (PMV)	*p* value	Result
27.29	39.50	41.50	0.652	NS
29.01	39.96	41.04	0.794	NS
30.83	39.56	41.44	0.530	NS
32.8	39.71	41.29	0.728	NS
34.66	39.50	41.50	0.646	NS
35.19	39.00	42.00	0.449	NS

NS (Not significant) *P is significant at* 0.05

Table 5: Result of descriptive statistics of predicted mean vote.

Indoor air temperature^{0}C	Predicted Mean Votes of males (PMV)	Predicted Mean Votes of females (PMV)
27.29	0.50	0.55
29.01	0.73	0.75
30.83	0.93	0.98
32.8	1.68	1.73
34.66	2.35	2.40
35.19	2.70	2.78

4. 4 Core body temperature

An independent sample t-test was used to compute gender difference in the core body temperature of the subjects, the result is summarised in Table 5 .The result in Table 5 shows that accross the six indoor temperature levels, there is no significant difference between core body temperature of the male and female subjets.However, it can be deduced from Table 5 that the core body temperature of the female subjects is a bit higher in all the six indoor temperature levels used to measure their mean core body temperature at the field study.

Table 6: Result of independent sample t-test showing gender difference in core body temperature

Indoor air temperature ^{0}C	Mean core body temp of males^{0}C	Mean core body temp of females ^{0}C	P value
27.29	36.76	36.80	0.329 NS
29.01	36.75	36.80	0.766 NS
30.83	36.79	36.81	0.674 NS
32.8	36.84	36.86	0.606 NS
34.66	36.86	36.87	0.802 NS
35.19	36.98	37.11	0.832 NS

NS (Not significant) *P is significant at* 0.05

5. Disscussion

Results from this study suggests that when it comes to persons that are thought to be acclamatised to tropical climate, there may be no signficant difference in the thermal comfort of male and female at **relatively high** indoor air temperature levels (27.29-35.19^{0}C), these temperatures represent the natural indoor air temperature levels in the classrooms when the themal comfort and core body temperature of the subjects were measured in this study. The indoor air temperature levels (27.29- 35.19^{0}C) was considred to be relatively high in this study,this because the indoor air temperature levels of 27.29 to 35.19^{0}C) used in this study are relatively higher than what ASHRAE (2004) prescribes for thermal comfort in hot seasons. Choi et al. (2010) documents that ASHRAE (2004) prescribes 23.3-27.8^{0}C as comfort temperature range indoors during hot seasons. The results concerning gender difference found out in this present study, complements the findings of several field and climatic chamber studies (Schiller et al., 1988; de Dear et al., 1991; Grivel & Candas, 1991; Karyono, 2002; Backer & Paciuk, 2009; Wong et al., 2009).These studies found out that given similar clothing insulation level and metabolic rate, there is likely not to be a significant difference in thermal comfort and preference male and female persons.

Furthermore, results from this study shows that there is a linear relationship between indoor air temperature and thermal discomfort, this means as temperature increased from 27.29 to 35.19^{0}C, thermal discomfort is likely to increases, this findings is in agreement with the hypotheses of Humphreys (1977), the author hypothesised that feeling of warmth is positively correlated to rise in temperature .

Again result in Table 5 shows that in all the six indoor air temperature levels, the predicted mean vote of the female subjects is slightly higher than those of the male subjects.The findings here, suggest that the female subjects were a bit warmer than the male subjects. This is probably based on the fact that it has been noted that women are more sensitive to deviations from optimal thermal conditions (Karjalainen,2012;Wang et al.,2018).

Additionally, results in Table 5 suggest that the subjects were thermally comfortable between 27.29 and 30.83^{0}C. Seemingly, Jimoh and Demenongu-Demshakwa, 2020) found out that persons in naturally ventilated office can be thermally neutral at 29.4^{0}C . these result suggest that people that are living in the tropics can tolerate high indoor air temperature than what (ASHRAE 2004) thermal comfort standards prescribes (23.3-27.8^{0}C). By extension,this result suggest that there is a need to develop thermal comfort standards for people living in the tropics that differs from international thermal comfort standards.

Lastly, when it comes to gender difference in core body temperature , result from this study(Table 6) suggest that there is no significant difference between the core body temperature of male and female.However result in Table6, shows that the core body temperature of females was a bit higher than those of males.This result resonates the findings by Mehnert et al.(2002) as cited in Karjalainen (2012). Mehnert et al.(2002) noted that under heat stress the core body temperature of females is a bit higher (0.2^{0}C) than those of females.

The implication of the results from this study is that when specifying indoor air temperature for school buildings in Nigeria it should not be based on a specific gender. Another implication of the results from this study is that thermal comfort temperature for schools should not be based on international standards e.g ASHRAE (2004).Furthermore, implication of the results from this study is that high indoor air temperature can increase core body

temperature, thus the health of children could be at risk.Therfore, avoinding high indoor air temperatures in classrooms should be of importance to designers of schools. Lastly, the implication of the results from this study is that the comfort temperatures found by previous reseach (e.g. Akande & Adebamowo, 2010; Jimoh & Demenongu-Demshakwa, 2020) in Nigeria may be applicable to male and female.

The key limitation of the findings from this study is that the number of subjects used for this study is small,thus this can limit the generalisation of the results to other populations in Nigeria. Another limitation of the results in this study is that, the equipment used for the measurement of core body temperature may not be the most appropraite, this is because there are other ways of measuring core body temperature e.g rectal and eardrum temperature. However, measuring rectal and eardrum temperature will require strict ethical procedure and approval which was difficult to obtain during this study. Lastly, a limitation from this study is that ,the study was not able to measure the thermal comfort and core body temperature of the subjects at relatively low indoor air temperature e.g 18^{0}C and below. This is because as at the time of this study the lowest indoor air temperature in the classroom is 27.29^{0}C.

6. Conclusion

This examined indoor air temperature in relation to difference in thermal comfort and core body temperature of male and female.The conclusions from the results are presented below.

- At relatively high indoor air temperatures (27.29- 35.19^{0}C), the thermal comfort of males does not significathly differs from those of females when it come to persons living in the tropics. By extention this suggest that the thermal comfort conditions found by previous reseach (e.g.Ogbona & Haris, 2007; Akande & Adebamowo, 2010; Adaji et al., 2017; Jimoh and Demenongu-Demshakwa, 2020) in Nigeria could be applicable to males and females
- Persons living in the tropics could tolerate high indoor air temperatures than what ASHRAE (2004) international thermal comfort standards prescribes.
- Increase in temperature from 27.29 to 35.19^{0}C can also lead to an increase in thermal discomfort.
- At relatively high indoor air temperature (27.29- 35.19^{0}C),the core body temperature of females is a bit higher than those of males

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