Comfort Limits for the Effective Temperature Index in the Tropics: A Nigerian Case Study

Dr. Olu Ola Ogunsote and Dr. Bogda Prucnal-Ogunsote

Department of Architecture, School of Environmental Technology, Federal University of Technology

Akure, Nigeria

Comfort conditions are established using a thermal index and this investigation examines the Effective Temperatures Index with the objective of proposing the comfort limits valid for Nigeria. A mental assessment test using rating scales was applied to 203 subjects and the results obtained analysed using various statistical and prediction techniques. The proposal of 20-25 degrees as the comfort limits is limited by the scope and duration of the study.

Introduction

Comfort is a subjective sensation. It is that state of mind that expresses satisfaction with the thermal environment. Alternatively, it is that state of mind that does not express dissatisfaction with the thermal environment. It is equivalent to conditions in which human beings can sleep soundly and work comfortably and when there is a minimum demand on the thermo-regulatory mechanisms of the body. Outside comfort exists discomfort, which is characterised by the degree and duration of thermal stress. The body attempts to maintain a stable internal temperature by balancing heat loss and heat gain (homeostasis). The body gains heat mainly through basal and muscular metabolism and additionally by convection, conduction and radiation. Heat is lost through work performance by conduction, radiation, convection, evaporation (sweat secretion) and skin diffusion, as well as by latent and dry respiration [Ref. 11]. The deep-tissue temperature may be maintained outside comfort conditions; however, large and prolonged variations in body temperature may threaten survival and cause death or damage through excessively low (hypothermia), or excessively high (hyperthermia) deep-tissue temperatures.

Comfort within dwellings is achieved partly by protecting buildings from heat gain during hot periods and by preventing heat loss during cold periods. When mechanical aids are employed for this purpose, they should only supplement passive methods [Ref. 15]. In either case knowledge of the thermal stress imposed by external conditions as well as the optimal thermal conditions needed for comfort within dwellings is necessary. Thermal stress and the optimal thermal conditions are measured with the aid of a thermal index.

Factors Affecting Thermal Comfort

There are six major factors that determine comfort. They are ambient air temperature, humidity, radiation, air movement, intrinsic clothing and level of activity. Other factors that may have some effect on thermal comfort are age, sex, body shape, state of health, ethnic grouping, diet, sleep, colour of clothing, acclimatisation, availability of fresh air, transients, colour of a space enclosure and noise [Ref. 3, 11]. An indication of the relative importance of these other factors is the fact that when all the six major factors are within an acceptable and optimal range, about 70% of the population will be comfortable.

The Thermal Indices

Knowledge of the way different variables affect thermal comfort has been used to formulate thermal indices or thermal scales that indicate the effects of combining the different variables on comfort. Over thirty of these indices have been devised although their definitions and ranges of applicability differ widely [Ref. 10]. An ideal index should reasonably accurately predict the consequences of any combination of the six major factors affecting comfort. It should be applicable both indoors and outdoors and it should be capable of indication the degree of discomfort. One of the most popular indices is the Effective Temperature Index.

The Effective Temperature Index

The Effective Temperature (ET) is defined as the temperature of a still, saturated atmosphere which would, in the absence of radiation, produce the same effect as the atmosphere in question [Figure 1]. It indicates the combined effects of relative humidity, air velocity, air temperature and clothing*.

The major merit of the index is that it indicates the effects of most of the major factors on comfort. In addition, the nomogram is simple and easy to use. It however has some limitations. It does not indicate the effect of radiation or show the degree of discomfort directly. There are nomograms for only two categories of clothing: normal indoor clothing and stripping to the waist. Analyses carried out by Glickman *et al*, Koch *et al,* Smith and Yaglou show that the index overestimates the effects of humidity under cool and comfortable conditions [Ref. 5, 9, 20, 21]. They also claim that it underestimates the effects of humidity at high temperatures and that it exaggerates the stress imposed by air velocity in hot environments. Givoni [Ref. 4] shows that the index made adequate allowance for air movement only below an ET value of 32 degrees Celsius. The index is valid for air temperatures between 0 and 45 degrees Celsius; wet bulb temperatures between 0 and 45 degrees Celsius and air velocity between 0.1 and 7 metres per second.

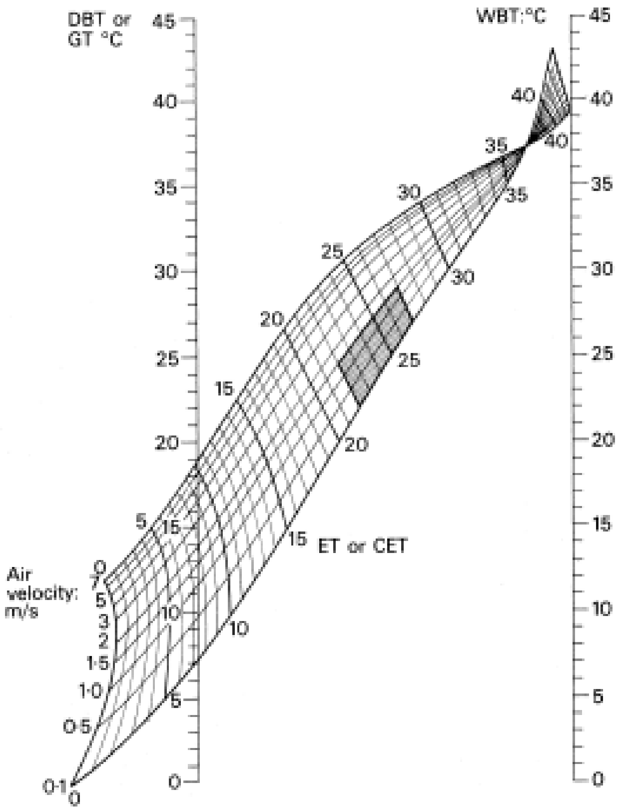

Figure 1: The Effective Temperature nomogram for persons wearing normal business clothing. Source: Koenigsberger et al.

The index requires that comfort limits be established for the location, zone or region and 22-27 degrees are assumed for the Tropics [Ref. 10]. This study aims at confirming these limits or proposing new ones.

Research Methodology

Psychophysical experiments are designed to set standards of building practice, to devise techniques to reach these standards and to discover means of assessing the success of a building in meeting these standards [Ref. 6]. Architectural psychophysics concerns the relationship between people and buildings. This differentiates it from psychological studies which deal with people. Thus a study by a psychologist concerning the reaction of human beings to heat and cold may not be directly applicable in building design. What is needed is how people perceive heat and cold in an architectural space.

There are three types of psychophysical experiments: performance tests, physiological tests and mental as-

* An improved index, the Corrected Effective Temperature (CET) additionally indicates the effect of radiation. This is achieved by using the globe temperature in lieu of dry bulb temperature.

sessment tests [Ref. 8]. The first two are behaviour studies while the third is an introspective study.

Performance Tests

These measure the ability of a human being to perform a given task under a range of physical conditions. The participant is not required to express opinions or to make any judgements. In a comfort study this may involve requesting participants to do a certain task in a room. The conditions of humidity, air temperature, radiation and air movement may be varied and the rate at which the work is performed measured. By varying the various environmental factors and measuring the corresponding work rates optimum conditions for work, and thus the comfort limits, may be established.

Physiological Tests of Subjective Responses

This type of experiment involves the measurement of some physical phenomenon of which the subject may not be aware. For example, in a study of thermal comfort the sweat rate, the rate of blood flow (heart beat rate) or elevation in body temperature may be measured under varying conditions. A graphical relationship might then be established between say, air temperature and sweat rate. Physiological tests are very useful in the determination of the effect of the environment on an organism. This usefulness is enhanced by the fact that the subject need not be aware of the purpose of the experiment and therefore his reaction is not influenced unduly. This unwanted influence is a result of the Hawthorne Effect*. They are however a poor means of assessing subjective responses. An example of this inadequacy is shown by an experiment that tries to establish thermal comfort on the basis of heart beat rate. The subject is not asked for an opinion or judgement in this type of test also.

Mental Assessment Tests

These involve the mental assessment of sensations that cannot be measured directly by subjects. The most commonly used methods of mental assessment are: rating scales, multiple-criterion adjustment, direct estimates of magnitude, comparison and a combination of these various methods. The common uses of these methods for comfort studies are discussed below.

Rating Scales: These are used when a condition is fixed or unalterable and it involves a long-term element. The thermal comfort in a room can be analysed using a rating scale. The observers are usually asked to rate the degree of comfort in the room according to given categories. Numbers are later assigned to these categories for the purposes of analysis [Ref. 1, 2].

Multiple-Criterion Adjustment: Multiple-criterion adjustment methods are used when the environment can be adjusted. A physical variable which produces an easily recognised change in the sensation being investigated is usually chosen. For example, an air-conditioning unit may be able to regulate air temperature, humidity and air-velocity. Subjects may then be asked to adjust the temperature knob until they are cold, comfortable or hot. Meanwhile the other variables remain unchanged.

Direct Estimates of Magnitude: This involves the direct mental estimates of magnitude. An example is a situation where a subject is asked to turn the temperature knob until he feels twice as cold. The methods used for this include multiplication and fractionation, interpolation or equal appearing intervals and that of direct numeration [Ref. 8].

The Method of Comparisons: This is used to evaluate a complete environment and to compare it to others in a qualitative rather than a quantitative way. Subjects may be asked to enter three rooms with differing environmental conditions in a random order. They may then be asked to rank each room according to how hot or cold in relation to other rooms it is.

Integrated Methods: These are used when it is obvious that the use of only one method will be inadequate or when considerable modification of a given method is required.

Observer Variance

The sensation reported by various individuals under the same conditions normally varies from individual to individual. There may be a degree of agreement between the majority but some subjects may disagree in a fundamental way. The analysis of experimental data should therefore be properly done using Biometrics Statistics [Ref. 8]. The most commonly used statistics are the mean, mode, median and inter-quartile range.

Some subjects deliberately give wrong assessments in an attempt to mislead the researcher. This can often be detected from the way such data differ from the rest. The temptation to discard such data may however lead to errors. An important variation, if examined properly, may lead to a discovery of new rela-

* The Hawthorne Effect was first noted in an experiment in Chicago involving the efficiency of workers under certain working conditions. The awareness of the workers that they were participating in an experiment was found to influence their response in an important way [Ref. 13]

tionships. The normal practice is not to discard extreme data unless they are the result of systematic disturbance in controlled conditions. The use of the inter-quartile range to give priority to majority response is however commonly used.

Choice of Methodology

The choice of an appropriate method was determined by limitations. The equipment needed to create artificial environments and to measure performance and biological variables was not available. A mental assessment test using rating scales was therefore designed. This has the advantage of providing mental assessments of the actual climatic conditions and not an artificially simulated environment. On the other hand, various subjects rate comfort under varying conditions, in different places, on different days and at different times. Comparison is thereby made more difficult. This comparison was made possible by using mathematical techniques to calculate a single variable, the Effective Temperature, common to each set of conditions. The comparisons are then based on the calculated Effective Temperatures.

The object of comparing the various comfort limits is to determine which one is most reliable in the prediction of thermal stress. It is possible to record the thermal stress experienced for various conditions and to predict the thermal stress for the same conditions using the various comfort limits. The recorded and predicted thermal stresses can then be compared. The best comfort limits will be consistently more successful at predicting the thermal stress in a wide range of environmental conditions.

Table 1

Frequency distribution of experienced thermal stress on a nine-point scale

Comfort conditions	Number of cases
very cold	5
Cold	14
Cool	38
comfortably cool	66
comfortable neutral	39
slightly warm	14
Warm	11
Hot	10
very hot	6
Total	203

Table 2

Frequency distribution of expereinced thermal stress on a five-point scale

Recoded thermal stress	Total number of cases	Cases selected for analysis
Very cold	5	5
Cold	52	48
Comfort	119	112
Hot	21	13
Very hot	6	3
Total	203	181

The Field Study

A form (questionnaire) was designed to record thermal stress on a nine-point scale along with other information of interest such as location; date; time; age; sex; height, weight and dressing of subject; and climatic conditions; wind, cloud cover, rainfall and shading*. Subjects were asked five questions including their state of thermal comfort. The researcher then recorded the answers along with other observations on the study form.

The study form (questionnaire) was used to document 203 cases on the Main Campus of Ahmadu Bello University, Zaria between August and October 1987. All cases where the subject was clothed heavily or not shaded from direct solar radiation were rejected. This left 181 cases for analysis.

The frequency distribution of experienced thermal stress on a nine-point scale is shown in Table 1. For uniformity the recorded comfort conditions were recoded to create only five groups and make analysis easier**. Comfortably cool, comfortable neutral and slightly warm were recoded as “comfort”. Cold and cool were recoded as cold, while warm and hot were recoded as hot (Table 2).

* The research covered various aspects of comfort and several thermal indices. This report documents only a limited and specific area of the study.

** This re-coding creates fewer groups and makes analysis easier. The use of a 5-point scale instead of a 9-point scale also reduces the chances of an error of prediction [Ref. 11, 19]. For thermal sensation scales see Ref. 11, p 52-57.

The next step was the calculation of the Effective Temperatures for the same time and day each subject was interviewed. The investigation made use of a data library in computer-readable form which contains climatic and related data and is organised with the use of database concepts. The date was used to obtain the minimum and maximum air temperature and relative humidity*. The minimum and maximum wet bulb temperatures were then calculated using the psychometric chart. Next, the minimum and maximum Effective Temperatures were determined for the air velocity obtained from the wind information using the Effective Temeperature nomogram**. The Effective Temperature for the given time was found with the aid of the hourly temperature calculator and the thermal stress finally determined by comparing the calculated Effective Temperature with the appropriate comfort limits using the method proposed by Prucnal-Ogunsote *et al* [Ref. 18]. Nine comfort limits were used to predict thermal stress: 19-25, 20-23, 20-24, 20-25, 20-26, 20-27, 22.5-25.5, 22-27 and 24-29 degrees Celsius. This procedure was repeated for each subject and for each set of comfort limits.

To facilitate easy computation and reliability and to make checking possible the computations were handled by a computer. Several routines were written in FORTRAN and these coupled with the existing suite of programs were used to determine the thermal stress [Ref. 14, 16, 17]. Routines were written to simulate the psychrometric chart, the Effective Temperature nomogram and the hourly temperature calculator. The statistical analyses were done with the aid of SPSS - Statistical Package for the Social Sciences on a mainframe computer, the Cyber 72 at the Iya Abubakar Computer Centre, Ahmadu Bello University, Zaria.

Statistical Analyses

The choice of the most appropriate comfort limits is based on ranking according to ability to predict thermal stress. The type of statistical technique used depends on the nature of the data and the level of measurement [Ref. 7]. The scales of measurement are nominal, ordinal, interval and ratio.

The five categories of thermal stress on a 5-point scale give an ordinal scale, since there are distinguishable groups with an order of magnitude among the groups, or an interval scale on the assumption that the units are the same size throughout. It is difficult to decide whether the differences between cold and comfortable on one hand, and hot and very hot on the other are the same. In making a decision, it should be noted that the level of measurement increases from nominal to ordinal to interval and to ratio. Interval-level data therefore have all the properties of ordinal-level data. It is also necessary to establish whether the data are continuous or discrete. Thermal stress can be measured on a continuous scale, but for the purposes of this study grouping into five categories has been used to obtain discrete data.

The statistical techniques used in the analysis of the data are the following: frequency analysis, ordinal-level data analysis and interval level data analysis.

Table 3

Frequency distribution of observed and predicted thermal stress

Comfort Limits	Very cold	Cold	Comfortable	Hot	Very Hot	Total
Observed	**5**	**48**	**112**	**13**	**3**	**181**
19 - 25	-	15	124	42	-	181
20 - 23	1	19	50	111	-	181
20 - 24	1	19	82	79	-	181
20 - 25	1	19	121	40	-	181
20 - 26	1	19	160	1	-	181
20 - 27	1	19	161	-	-	181
22.5 - 25.5	16	49	96	20	-	181
22 - 27	12	35	134	-	-	181
24 - 29	26	74	79	-	-	181

* The data library containes long-term averages of climatic data for 15-day periods.

** The four categories calm, slight breeze, strong breeze and strong wind are graded as 0.5, 2.5, 4.5 and 7.0 m/s respectively. The speed at body level is obtained by applying a reduction factor of 0.3.

Frequency Analysis

Frequency analysis may give an indication of the relationship between the predicted and observed thermal stress. There are three frequency analyses used in this study.

Frequency Distribution of Error of Prediction. The frequencies of predicted thermal stress for the various comfort limits as well as the corresponding frequencies of observed thermal stress are shown in Table 3. By subtracting the observed thermal stress from the predicted thermal stress we obtain the "error of prediction", the frequency distribution of which is shown in Table 4. The error of prediction indicates the degree and nature of variation between predicted and observed thermal stress. For a correct prediction, the error of prediction is zero. For observed comfortable conditions, comfort limits that tend to predict cold discomfort will accumulate negative errors of prediction while comfort limits that tend to predict hot discomfort will accumulate positive error of prediction. The frequency distribution may be quantified by the mean, mode median, sum, range, skewness and standard deviation. These statistics for the various comfort limits are shown in Table 5. It should be noted that the skewness is measured about the mode, and not the central value 0 [Ref. 6]. The following comfort limits have relatively low errors of prediction: 20-27, 20-26, 20-25, 22-27, 19-25 and 22.5-25.5.

Table 4

Frequency distribution of error of prediction.

Comfort Limits	Difference between recorded and predicted thermal stress						
	-3	-2	-1	0	+1	+2	+3
19 - 25	-	3	15	90	59	14	-
20 - 23	-	1	18	47	83	30	2
20 - 24	-	3	17	66	71	23	1
20 - 25	-	3	19	90	55	14	-
20 - 26	-	4	25	105	42	5	-
20 - 27	-	4	26	104	42	5	-
22.5 - 25.5	1	15	42	76	41	6	-
22 - 27	1	11	38	93	33	5	-
24 - 29	4	20	64	69	23	1	-

Table 5

Statistics of error of prediction.

Comfort Limits	Mean	Median	Sum	Standard Deviation	Mode	Skewness
Ideal	**0**	**0**	**0**	**Small**	**0**	**0**
19 - 25	0.35	0.31	66	0.81	0	-0.061
20 - 23	0.71	0.80	129	0.92	1	-0.272
20 - 24	0.54	0.54	97	0.91	1	-0.196
20 - 25	0.32	0.26	58	0.83	0	-0.006
20 - 26	0.11	0.09	19	0.75	0	-0.093
20 - 27	0.10	0.08	18	0.75	0	-0.087
22.5 - 25.5	-0.12	-0.07	-22	0.98	0	-0.215
22 - 27	-0.11	-0.07	-20	0.89	0	-0.261
24 - 29	-0.50	-0.46	-91	0.95	0	-0.229

The Cumulative Frequency of Error of Prediction shows the cumulative percentage of successful predictions given error levels of 0, ±1, ±2, ±3, or ±4. An ideal index should make a 100% successful prediction at the zero error level. This type of analysis however has a few drawbacks inherent in the distribution of observed thermal stress. In the study, 2.8% of the subjects expressed very cold discomfort, 26.5% expressed cold discomfort, 61.9% expressed comfort, 7.2% expressed hot discomfort while 1.7% expressed very hot discomfort. Thus an index which is incapable of detecting hot or cold discomfort and always predicts comfort will seem to be a good index. Wide comfort limits such as 20-26 and 20-27 therefore perform better than narrow comfort limits such as 20-23 and 20-24. See Table 6.

Ability to Predict Overheating, Comfort and Under-heating: An alternative approach is to determine the ability of the index to predict hot discomfort, comfort and cold discomfort. For this purpose hot discomfort and very hot discomfort are grouped as overheating while cold discomfort and very cold discomfort are grouped as underheating. The percentages of successful predictions for underheating, comfort and overheating are given in Table 7. This table shows that all the comfort limits exhibit a bias in their ability to predict thermal stress. Some are good at predicting under-heating while others are capable of detecting overheating. On average, the best limits are 20-25 and 20-23.

Table 6

Cumulative frequency distribution of error of prediction

Comfort Limits	Error of prediction				Rank
	0	±1	±2	±3	
20 - 26	58.0	95.0	100.0	-	1
20 - 27	57.5	95.1	100.0	-	2
20 - 25	49.7	90.6	100.0	-	3
19 - 25	49.7	90.6	100.0	-	4
20 - 24	36.5	85.1	99.5	100.0	5
22.5 - 25.5	42.0	87.9	99.5	100.0	6
22 - 27	51.4	90.6	99.5	100.0	7
20 - 23	26.0	81.8	99.0	100.0	8
24 - 29	38.1	86.2	97.8	100.0	9

Table 7

Percentage of successful predictions for comfortable, under heated and overheated conditions.

Comfort Limits	Success ratings				Rank
	Under-heated	Comfort	Over-heated	Average	
20 - 25	11.3	68.8	56.3	45.5	1
19 - 25	7.5	69.6	56.3	44.5	2
20 - 23	11.3	27.7	87.5	42.2	3
20 - 24	11.3	45.5	68.8	41.9	4
22.5 - 25.5	43.4	51.8	12.5	35.9	5
20 - 26	11.3	88.4	6.3	35.3	6
24 - 29	62.3	42.9	-	35.1	7
22 - 27	28.3	73.2	-	33.8	8
20 - 27	11.3	88.4	-	33.2	9

Ordinal level data analysis

Ordinal level data analysis treats both the observed and the predicted thermal stress as ordinal level data. In this case the difference between cold and comfortable needs not be the same as that between comfortable and hot. Correlation between ordinal level data is analysed using Spearman correlation coefficient (rho), Kendall correlation coefficient (tau) and Gamma test of statistical significance.

Gamma Test of Statistical Significance
Gamma is the probability of correctly guessing the order of a pair of cases on one variable once the other variable is known. The sign indicates the direction of ordering.

Kendall's Rank-Order Correlation Coefficient (tau)
Kendall's tau is a standardised coefficient based on the amount of agreement between two sets of ordinal rankings. Kendall's tau is very similar to Spearman's rho but the Kendall's coefficient is more meaningful when the data contain a large number of tied ranks. Kendall's tau is non-parametric because it does not depend upon a normal distribution or the metric quality of interval scales.

Spearman's Rank-Order Correlation Coefficient (rho):
Spearman's rho is defined as the sum of the squared differences in the paired ranks for two variables over all cases, divided by a quantity which is what the sum of the squared differences would have been had the two sets of rankings been totally independent. Spearman's rho is very similar to Kendall's tau but it seems to yield a closer approximation to product-moment correlation coefficients when the data are more or less continuous. This is the case when the data are not characterised by a large number of ties at each rank. It is a non-parametric correlation because no assumptions are made about the distribution of cases on the variables.

These coefficients are shown in Table 8. The comfort limits 19-25 and 20-25 show the highest correlation.

Interval level data analysis

Interval level data analysis treats both the observed and the predicted thermal stress as interval level data. In effect, the comfort conditions very cold, cold, comfortable, hot and very hot are assumed to occur at equal intervals on the comfort scale. Interval level data are examined for correlation using two statistics: Pearson correlation coefficient and Eta correlation ratio [Ref. 7].

The Pearson Correlation Coefficient (r)
The Pearson correlation coefficient is used to measure the strength of relationship between two interval level variables. The strength of relationship indicates the goodness of fit of a linear regression line to the data. It also indicates, when r is squared, the proportion of variance in one variable explained by the other. The cut-off point for the Pearson correlation coefficient given 200 cases is 0.117. For the significance to be acceptable, it should be less than 0.05.

Eta Correlation Ratio (Eta Test of Statistical Significance)
Eta correlation ratio is the common name for eta-squared and it has an intuitive interpretation as the proportion of variance in the dependent variable accounted for by the independent variable. Eta is a measure of the association between two variables used when the independent variable is nominal level and the depend-

Table 8

Gamma, Kendall's tau b and Spearman's rho

Comfort Limits	Gamma	Tau b	Significance (Tau b)	Rho	Significance (Rho)
19 - 25	0.26	0.135	0.007	0.146	0.051
20 - 25	0.25	0.134	0.008	0.146	0.051
20 - 23	0.23	0.122	0.015	0.132	0.075
22.5 - 25.5	0.21	0.118	0.018	0.134	0.074
20 - 24	0.19	0.109	0.031	0.116	0.113
24 - 29	0.16	0.094	0.062	0.103	0.167
20 - 26	0.14	0.046	0.359	0.048	0.520
22 - 27	0.11	0.052	0.297	0.056	0.457
20 - 27	0.07	0.020	0.685	0.021	0.778

ent variable is interval or ratio level. It shows how the means of the dependent variable are within the categories of the independent variable.

The Pearson correlation coefficients and the Eta correlation ratios for the various comfort limits are shown in Table 9. The highest correlation is shown by the comfort limits 20-25.

Comfort Limits for the Effective Temperature Index

Table 10 shows a summary of the optimal comfort limits using various methods. Although the various methods give different results, there is still a discernible tendency towards wide comfort limits. The optimal comfort limits are also consistently lower than the 22-27 degrees recommended by Koenigsberger *et al.* The limits recommended by Koenigsberger *et al* are comparably poor in predicting thermal stress. The summary indicates that the optimum comfort limits using this Effective Temperature Index for Zaria (and by association, other parts of the country), are 20-25 degrees Celsius with the following limitations.

1. The thermal stress is predicted on the basis of average climatic data and not the actually experienced conditions.
2. The field study covered only 3 months of the year.
3. The study covers only day thermal stress
4. The field study was carried out only in Zaria.

Table 9

Pearson correlation coefficients and eta correlation coefficients.

Comfort Limits	Pearson Correlation Coefficient		Eta Correlation Ratio		Rank
	Coefficient	Significance	OTS dependent	PTS dependent	
20 - 25	0.154	0.019	0.21	0.22	1
19 - 25	0.147	0.024	0.20	0.21	2
20 - 23	0.131	0.039	0.19	0.15	3
22.5 - 25.5	0.121	0.052	0.19	0.13	4
20 - 24	0.113	0.065	0.15	0.16	5
24 - 29	0.090	0.113	0.14	0.13	6
20 - 26	0.063	0.201	0.16	0.12	7
22 - 27	0.045	0.275	0.05	0.13	8
20 - 27	0.035	0.318	0.09	0.09	9

Legend: OTS = Observed Thermal Stress; PTS = Predicted Thermal Stress.

Table 10

Choice of comfort limits

Method	Comfort Limits		
	Best	2nd Best	3rd Best
Distribution of error of prediction	20-26	20-27	20-25
Skewness of error of prediction	20-25	19-25	20-27
Cumulative frequency of error of prediction	20-26	20-27	20-25
Ability to predict overheating, comfort and underheating	20-25	19-25	20-23
Gamma test of statistical significance	19-25	20-25	20-23
Kendall's rank-order correlation coefficient (tau)	19-25	20-25	20-23
Spearman's rank-order correlation coefficient (rho)	20-25	19-25	22.5-25.5
Pearson correlation Coefficient (r)	20-25	19-25	20-23
Eta correlation ratio (PTS dependent)	20-25	19-25	20-24
Summary	20-25	19-25	20-23

5. The study covered only external conditions, light or normal clothing, healthy subjects, calm or light breeze, shade, sedentary activity and open spaces with low or medium building density.
6. A study that sets the lower and upper comfort limits separately may produce more accurate comfort limits.

Conclusion

This study concludes that the most appropriate comfort limits for the Effective Temperature Index in Zaria are 20-25 degrees Celsius. The study is however limited by the scope and duration. A confirmation of this proposal may require the extension of the investigation to other regions and seasons, and the modification of analytical techniques to set lower and upper comfort limits separately.

Acknowledgements

Methods of statistical analysis were consulted with Professor J. A. Oladipo of the Iya Abubakar Computer Centre and Professor E. B. Ebong of the Department of Mathematics, both statisticians at the Ahmadu Bello University, Zaria. Professor B. K. Olorukooba also made useful contributions on computer analyses of subjective variables.

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