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Article

Investigation on Hourly and Monthly Thermal Comfort in the Humid Tropics of Malaysia

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Abstract: Investigations on hourly and monthly indoor neutral temperature variations in the humid tropics are limited in literature. In Malaysia, the variation of hourly outdoor mean temperature is slightly higher than the monthly mean temperature. Consequently, this leads to the hypothesis that the variation of hourly neutral temperatures might be higher than the monthly neutral temperatures. Understanding the impact of hourly and monthly temperature variation on thermal comfort will certainly provide the design direction of future indoor environments. In this study, extensive measurements from residential buildings were used to investigate the observed variation. Linear regression and Griffiths methods were explored for analyzing the results. There was almost no variation on hourly and monthly neutral temperatures within the range under study. Further research is highly recommended due to the limited data collection and the limitations of the employed methods. It is highly advised to further investigate the hourly temperature variation on thermal comfort during nighttime and early morning. This is for an accurate interpretation of the results.

Keywords: comfort temperatures; humid tropics; Griffiths method; climate; buildings; concept

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1. Introduction

Biological time-keeping mechanisms have fascinated many researchers [1]. They are usually referred to as a system's rhythm [2]. This is because they affect the daily rhythm of many physiological processes. The body rhythms are called circadian rhythms. These circadian rhythms are generally well known, *i.e.*, the heartbeats in the human chest. Despite the fact that circadian rhythms tend to be coordinated with cycles of light and dark, it has been reported that other factors, such as ambient temperature, can influence the timing as well. Human body temperature also varies naturally over the course of a day. Humans and climate as a part of the global environment are subjected to temperature cycles.

Though many researchers have investigated the diurnal variations in human internal body temperature [3–5], few investigators have addressed the impact of such variations on people's thermal comfort in the equatorial fully humid climate. For instance, little is known on how people thermally perceive the variation of the hourly and monthly temperatures in naturally ventilated residential buildings. Thus, the goal of this research is to investigate the effect of seasonal, monthly, and hourly temperature variations on thermal comfort. Kota Kinabalu was selected for the assessment.

In the equatorial fully humid climate, the seasonal variation of the outdoor climate is usually described as rainy and dry seasons. This is because the monthly variation of the mean outdoor air temperature is very narrow. Generally, it lies within 25 to 27 °C [6]. In Kota Kinabalu (Figure 1), there are only wet and dry seasons. The wet season typically spans the months of October to March. The dry season spans the months of April to September. Kota Kinabalu's climate is characterized by a relatively uniform temperature, high humidity, and a high amount of cloud cover. Kota Kinabalu is also exposed to intense solar radiation.

Figure 1. The location of Kota Kinabalu City.

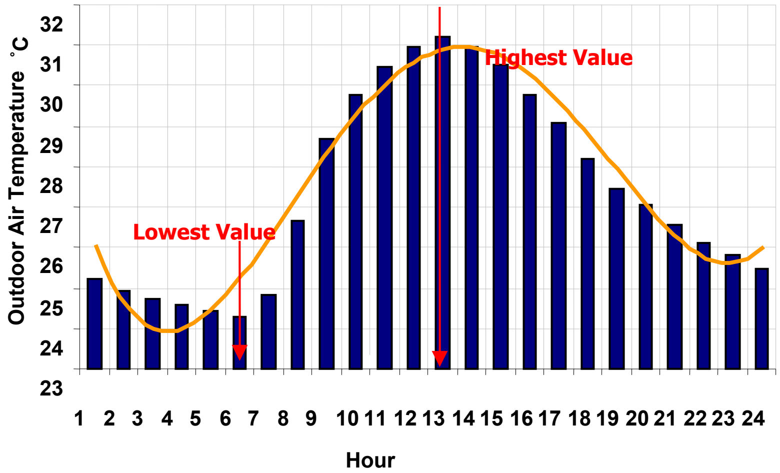
The mean outdoor air temperature in Kota Kinabalu is about 27.5 °C [7]. The monthly mean outdoor air temperature has a very narrow range of 1.6 °C. The diurnal temperature range is approximately

6.9 °C. The monthly temperature range is smaller than the daily range. Thus, it provides the basis for a saying generally quoted by climatologists: "Night is the winter of the tropics" [6]. It is not clear as to whether or not hourly neutral temperature variation is wider than the monthly neutral temperatures in the equatorial humid tropics. This requires further investigation.

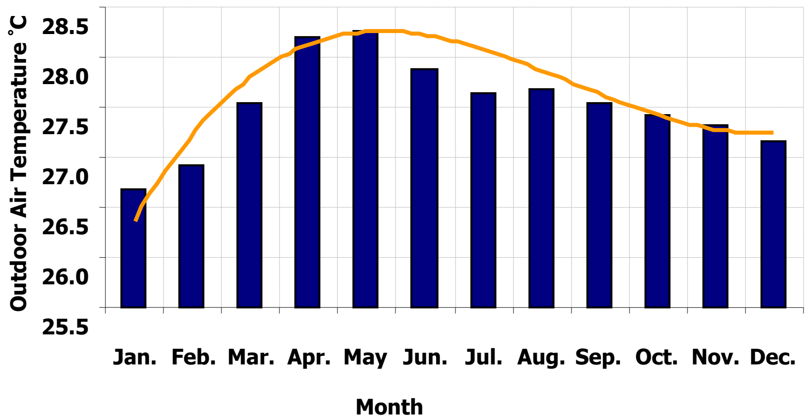
The mean monthly and hourly indoor air temperatures of Kota Kinabalu are plotted in Figure 2. The plots illustrate the pattern of variation of the mean monthly and hourly outdoor air temperatures.

The highest mean monthly outdoor air temperature was recorded in May (28.3 °C) and the lowest value in January (26.7 °C). The highest hourly outdoor temperature was recorded at 1 p.m. (31.2 °C) and the lowest value at 6 a.m. (24.3 °C).

The plotted data further confirmed that the monthly temperature range in Kota Kinabalu is narrower than the hourly temperature range.



(**a**)



(**b**)

Figure 2. (**a**) Mean hourly (2001–2005) and (**b**) Mean Monthly (1968–2003) Outdoor Temperatures.

2. Methodology

To address the question raised in the introduction, extensive field measurements in residential buildings were carried out over a period of one year in Kota Kinabalu. The number of the surveyed subjects was 949 records. Records were reduced to 890 when filtered against the criteria established before analysis. Nearly 42% of the participants were males and 58% were females. The participant demographic information is listed in Table 1. In this study, the ASHRAE seven-point scale was selected for describing occupants' thermal perceptions toward the indoor comfort temperature. It has been reported that sensations such as "hot" or "cold" occur when the neural signal reaches the cerebral cortex. Perception is a process that elaborates and assigns meaning to the incoming sensory patterns [8]. Therefore, the focus in this investigation is on subjects' thermal perceptions toward the indoor thermal environment. However, in this article, the two terms will be used to refer to thermal perception. This is because they have been used widely in describing subjects' thermal perceptions in thermal comfort investigations. In this research, the comfort temperatures were predicted by linear regression and Griffiths methods.

Table 1. Participant demographic information.

Gender	Age								Total
	15–19	20–30	31–40	41–50	51–60	61–70	71–80	Blank	
Female	44	228	154	68	22	4	-	-	520
Male	35	148	92	65	18	8	2	1	369
blank	-	-	1	-	-	-	-	-	1
Total	79	376	247	133	40	12	2	1	890

3. Results and Discussion

Prior prediction of hourly and monthly neutral temperatures and the relationship between thermal perception votes (*VASH*) and the indoor air temperatures (T_i) were developed. It was described with the following:

$$VASH = 0.395T_i - 11.875 \quad (1)$$

where, $F = 186.65$, p-value $= 1.04 \times 10^{-38}$, $R^2 = 0.174$, $n = 890$.

3.1. Prediction of Neutral Temperature during Wet and Dry Seasons

Linear least squares regression was used to predict the indoor neutral temperature during the wet and the dry season. For the wet season, the indoor neutral temperature was nearly 30.2 °C ± 0.2 ($F = 82.20$, p-value = 0.003, $R^2 = 0.943$, slope = 0.351, C.I. (confidence interval) of the slope = 0.251–0.450, intercept = −10.607, $n = 483$). Similarly, the neutral temperature estimated during the dry season was 30.0 °C ± 0.3 ($F = 114.64$, p-value = 0.004, $R^2 = 0.966$, slope = 0.369, C.I. of the slope = 0.273–0.465, intercept = −11.060, $n = 407$). Hence, in the present study, the difference in neutral temperature between seasons was small enough that is unlikely to have a perceptible effect.

3.2. Prediction of Monthly Indoor Neutral Temperatures Using Linear Regression Model

Monthly indoor neutral temperatures were determined from the dataset. The obtained results are listed in Table 2. In July, the coefficient of correlation was relatively high ($r = 0.492$) and the number of votes was small (only 22). Consequently, the obtained result might not be valid. Overall, the monthly neutral temperatures were close to 30 °C. The neutral temperature range was no more than 0.6 °C.

This is when the p-value was less than 0.05. In November, despite the reduced coefficient of correlation ($r = 0.194$) and the insignificant p-value, the predicted neutral temperature was close to 30 °C.

To further pursue the variation of the monthly mean indoor air temperature on the indoor neutral temperature, the mean monthly thermal perception votes were calculated. The results are plotted *vs.* the monthly mean indoor air temperature in Figure 3.

The regression line fitted to these values was statically significant. The predicted neutral temperature compared well with the predicted indoor neutral temperature in Equation (1). The neutral temperature based on the mean monthly records was about 30.1 °C ± 0.1 °C ($F = 126.26$, p-value = 5.41 × 10.07, $R^2 = 0.927$, slope = 0.4435, C.I. of the slope = 0.356–0.531, intercept = 13.371).

Table 2. Determination of monthly neutral temperatures.

Months	*r*	S	I	*F*	*p-Value*	No Votes	Neutral Temperature
January	0.525	0.399	−11.884	25.50	0.0000	69	29.8
February	0.392	0.485	−14.603	15.06	0.0002	85	30.1
March	0.386	0.916	−27.334	13.10	0.0005	77	29.8
April	0.399	0.397	−12.160	13.79	0.0004	75	30.6
May	0.374	0.386	−11.379	12.69	0.0006	80	29.5
June	0.416	0.553	−16.899	13.79	0.0004	68	30.6
July	0.492	0.835	−25.858	6.39	0.0200	22	31.0
August	0.337	0.428	−12.918	11.76	0.0009	94	30.2
September	0.163	0.150	−4.137	1.80	0.1839	68	27.6
October	0.286	0.299	−8.876	6.84	0.0107	79	29.7
November	0.194	0.206	−6.154	2.77	0.1003	74	29.9
December	0.275	0.389	−11.679	7.99	0.0057	99	30.0

Note: *r*, correlation coefficient; S, slope; I, intercept.

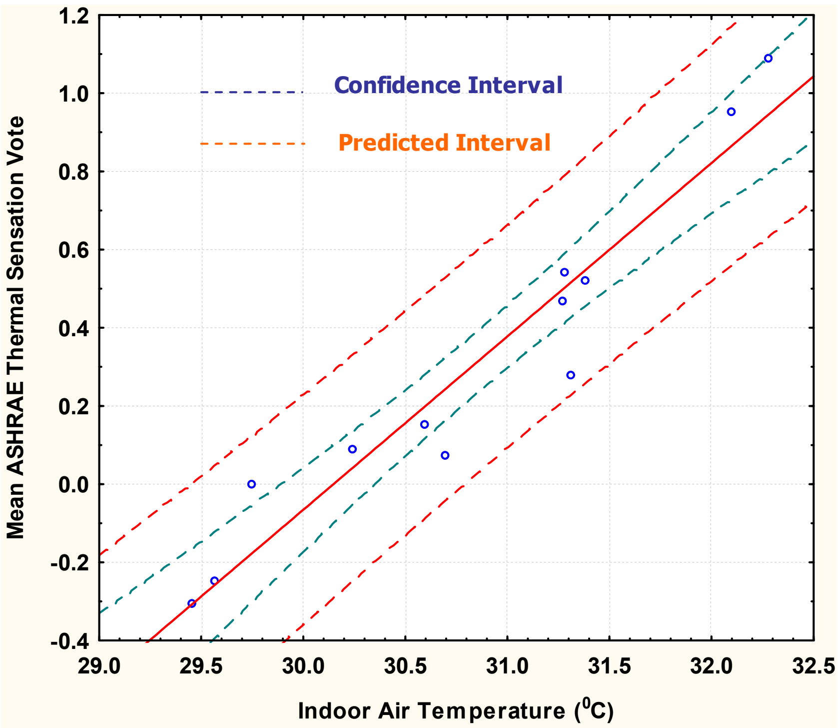


Figure 3. Monthly mean air temperature (°C) *vs.* mean votes on the ASHRAE scale.

3.3. Prediction of Hourly Indoor Neutral Temperatures Using Linear Regression Model

Hourly indoor neutral temperatures were determined from the dataset. The obtained results are listed in Table 3. It is apparent that the hourly neutral temperatures were close to 30 °C. This is when the *p*-value was significant at 0.05. However, the determined neutral temperature around 4 p.m. was relatively low at 29.1 °C.

Table 3. Determination of hourly neutral temperatures.

Hour	*r*	S	I	*F*	*p*-Value	No. Votes	Neutral Temperature
9	0.132	0.293	−9.673	0.23	0.6389	15	33.0
10	0.343	0.301	−9.197	10.94	0.0014	84	30.5
11	0.245	0.289	−8.658	6.08	0.0155	97	30.0
12	0.407	0.455	−13.690	19.07	3.19×10^{-5}	98	30.1
13	0.450	0.400	−12.216	21.86	1.08×10^{-5}	88	30.5
14	0.509	0.564	−17.146	31.52	2.17×10^{-5}	93	30.4
15	0.472	0.434	−13.114	24.70	3.37×10^{-5}	88	30.2
16	0.364	0.277	−8.074	13.12	0.0005	88	29.1
17	0.309	0.284	−8.403	8.96	0.0036	87	29.6
18	0.541	0.519	−15.587	31.00	3.82×10^{-5}	77	30.1
19	0.269	0.275	−8.170	3.89	0.0542	52	29.7

Note: *r*, correlation coefficient; S, slope; I, intercept.

Hourly indoor temperatures were further investigated from 10 a.m. to 7 p.m. Figure 4 illustrates the pattern of variation of occupants' thermal perceptions at various times of the day. The highest hourly mean thermal perception vote was about 0.6. This was observed around 4 p.m. The mean minimum value was about −0.1. It was observed around 10 a.m. Due to the limited data, the mean thermal perception vote around 9 a.m. was discarded.

The neutral indoor air temperature was also determined from the mean hourly indoor air temperatures and mean thermal perception votes. The results are plotted in Figure 5. The mean neutral indoor temperature was 30.3 °C ± 0.2 (F = 33.4, p-value = 0.002, R^2 = 0.770, slope = 0.625, C.I. of the slope = 0.384–0.866, intercept = −18.957).

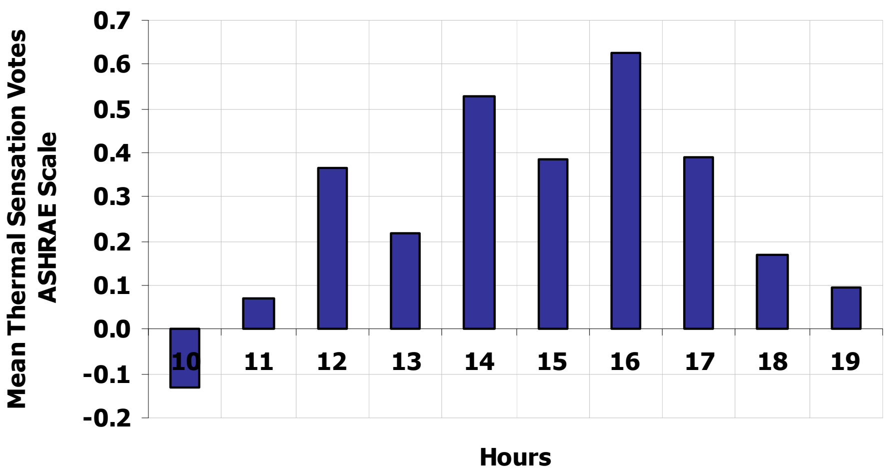


Figure 4. Hourly mean thermal sensation vote on the ASHRAE scale.

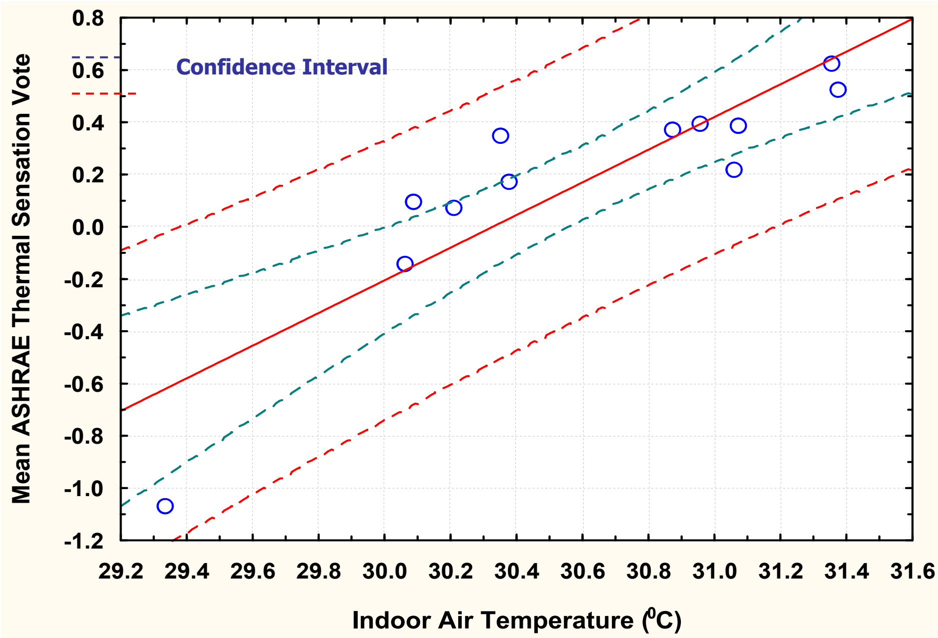


Figure 5. Mean hourly air temperature (°C) *vs.* mean votes on the ASHRAE scale.

Further analysis suggested one explanation as to why the neutral temperature predicted from the mean hourly data was in close agreement with that predicted from the mean monthly data. The mean monthly indoor air temperatures were within the range of 29.5 to 32.3 °C. The range is 2.8 °C. The mean indoor hourly indoor air temperature range was even narrower at 2.1 °C. The mean hourly temperature varied from 29.3 to 31.4 °C. This unexpected result could be attributed to the relatively small variation of the mean hourly indoor air temperature from 9 a.m. to 7 p.m. in the surveyed locations. In Kota Kinabalu, the lowest outdoor temperature usually occurs around 4 to 6 a.m. (Figure 2). Unfortunately, there was almost no field study around that time. Detailed hourly field surveys around that time would be worth pursuing in a more focused study. It is recommended to be carried out in wooden houses. This is because the range of indoor air temperatures in wooden houses is larger as compared to concrete houses [7].

3.4. Prediction of Monthly and Hourly Comfort Temperatures Using the Griffiths Method

The Griffiths method has been widely applied for thermal comfort predictions [9–11]. The Griffiths method was also exploited in the derivation of the EN 15251 adaptive comfort equation [12]. The main difference between the Griffiths method and the least square regression method is the slope regression. The slope regression is imposed when using the Griffiths concept.

Nicol *et al.* provided a comprehensive explanation about the method [13]. They reported that the Griffiths method faced a reliability issue in predicting comfort temperatures from small numbers of subjects. Consequently, the Griffiths method assumed that there was 3 K difference for one unit in the seven-point scale from climate chamber studies [13]. It has been reported that 0.25 is often applied in the field surveys, and 0.33 has been used by Fanger in laboratory experiments [14]. The slope of 0.5 is the regression coefficient often utilized recently [14]. It might be worth mentioning that 0.33 was established by climate chamber research for sedentary people in standard clothing (0.6 clo) [15]. The main issue in applying the Griffiths method is the accurate selection of the slope of the regression equation [16]. However, it was advised to use a standard regression gradient. This is instead of using the empirical value from each individual survey. A standard regression gradient above 0.4 was recommended from meta-analysis investigation [15]. In 1975, the standard regression gradient developed from meta-analysis was 0.25 scale units/K [15]. The authors attributed the discrepancy between the two studies to the duration of the thermal comfort field survey. The field studies in older surveys were longer than in the recent surveys such as the SCAT (Smart Control and Thermal Comfort) database. Consequently, the discrepancy was traced to behavioral adaptation which took place in older studies and reduced the slope regression. The present investigators did not find any information on how the Griffiths equation was mathematically developed. Therefore, the equation was first developed for further interpretation of the results. The general equation for predicting neutral from the least square equation may be written:

$$VASH_i = a \cdot T_i + b \tag{2}$$

The parameters "*a*" and "*b*" can be determined using numerical or statistical methods. The coefficients "*a*" (slope) and "*b*" might be estimated from Equations (3) and (4) [17].

$$a = \frac{n\sum T_i \cdot VASH_i - \sum T_i \sum VASH_i}{n\sum T_i^2 - \left(\sum T_i\right)^2} \tag{3}$$

$$b = VASH_{(mean)} - a \cdot T_{i(mean)} \tag{4}$$

Figure 6 shows a typical thermal comfort graph. From the figure, it is apparent that

$$\tan\alpha = a = -b/T_{(neutral\ mean)} \tag{5}$$

$T_{(neutral\ mean)}$ is the mean neutral temperature, $T_{(mean)}$ is the indoor mean temperature, $VASH_{(mean)}$ is the mean vote on the ASHRAE scale, "*a*" is the regression gradient (slope), and "*n*" is the number of subjects.

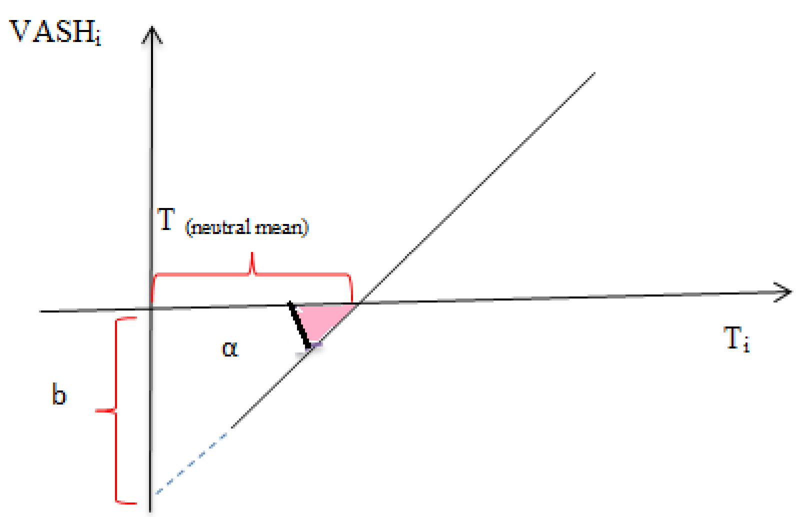


Figure 6. Typical thermal comfort graph.

Equation (4) into Equation (5) yields to:

$$T_{(neutral\ mean)} = T_{i(mean)} - VASH_{(mean)}/a \tag{6}$$

The slope "*a*" in the Equation (6) is influenced by the Griffiths concept. For further exploring concept, we developed a new procedure for all possible cases from Equation (6). The neutral temperature might be predicted from the following simplified equation:

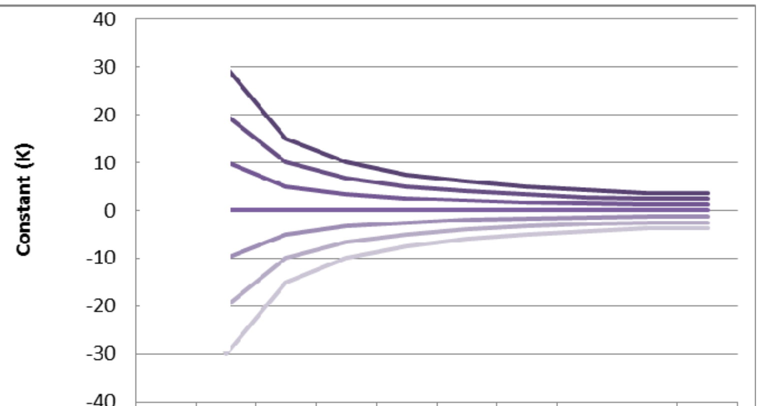
$$T_{(neutral\ mean)} = T_{i(mean)} + k_{(constant)} \tag{7}$$

where k is a constant which can be determined from Equation (8).

$$k_{(constant)} = VASH_{(mean)}/a \tag{8}$$

The constant ($k_{(constant)}$) requires knowledge of the mean vote on the seven-point ASHRAE scale and the slope of the equation. The results are plotted in Figure 7.

From Figure 7 it is apparent that the constant $k_{(constant)}$ is converging toward a narrow range with the increase of the gradient slope. The figure also shows that the neutral temperature is independent of the slope when the mean vote is close to neutrality. This means that the method might not necessarily provide an accurate prediction with a small sample size. This is because there will be no correction in such a case.



	Slope	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Cold	-3	30.00	15.00	10.00	7.50	6.00	5.00	4.29	3.75	3.75
Cool	-2	20.00	10.00	6.67	5.00	4.00	3.33	2.86	2.50	2.50
Slightly Cool	-1	10.00	5.00	3.33	2.50	2.00	1.67	1.43	1.25	1.25
Neutral	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slightly Warm	1	-10.00	-5.00	-3.33	-2.50	-2.00	-1.67	-1.43	-1.25	-1.25
Warm	2	-20.00	-10.00	-6.67	-5.00	-4.00	-3.33	-2.86	-2.50	-2.50
Hot	3	-30.00	-15.00	-10.00	-7.50	-6.00	-5.00	-4.29	-3.75	-3.75

Figure 7. The developed constant $k_{(constant)}$ from the Griffiths concept.

It might be important to mention that most of the issues with the Griffiths method were traced back to the regression gradient. The correct Griffiths coefficient could not be determined with certainty [18]. Equation (7) reveals that when the mean vote is above neutrality, the accuracy in predicting the comfort temperature does not only depend on the slope but also on the reliability of the mean vote and mean temperature. This adds a further issue to the validity of the least square linear regression and the Griffiths methods with a small sample size. How accurate is the neutral temperature if the collected data is not enough to be representative? This article will not answer this question. It requires meta-analysis. The author developed a different methodology. Currently, the article is under review. Therefore, it will not be discussed here.

In this investigation, we developed Equation (8) from the Griffiths concept. It provides quite close results to those obtained from Equation (6). This equation may partly explain the reason behind finding similar results when using different regression methods.

$$T_{(neutral\ mean)} = T_{i(mean)} - ((1.025344514 \times (a^{-0.983277281})) \times T_{ASH(mean)} \quad (9)$$

In this study, the Griffiths method was used for exploring the hourly and monthly comfort temperatures. The monthly mean neutral temperatures were close to the overall neutral temperature. This is when the regression slope was close to 0.4 (Table 4). It is necessary to highlight that validation of the results is recommended.

The procedure of calculation is repeated with the hourly data. The results are listed in Table 5. The mean hourly neutral temperatures were close to the overall neutral temperature when the regression slopes were near 0.4. The hourly records at 9 a.m. were removed due to the small number of data. However, further validation is required.

Table 4. Mean monthly comfort temperature according to the Griffiths method.

Month	$T_{i(mean)}$	$VASH_{(mean)}$	***a* = 0.1**	***a* = 0.2**	***a* = 0.3**	***a* = 0.4**	***a* = 0.5**	***a* = 0.6**	***a* = 0.7**	***a* = 0.8**
1	29.8	0	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8
2	29.5	−0.3	32.5	31	30.5	30.3	30.1	30.0	29.9	29.9
3	29.6	−0.2	31.6	30.6	30.3	30.1	30	29.9	29.9	29.9
4	31.3	0.3	28.3	29.8	30.3	30.6	30.7	30.8	30.9	30.9
5	32.3	1.1	21.3	26.8	28.6	29.6	30.1	30.5	30.7	30.9
6	30.7	0.1	29.7	30.2	30.4	30.5	30.5	30.5	30.6	30.6
7	32.1	1	22.1	27.1	28.8	29.6	30.1	30.4	30.7	30.9
8	31.4	0.5	26.4	28.9	29.7	30.2	30.4	30.6	30.7	30.8
9	31.3	0.5	26.3	28.8	29.6	30.1	30.3	30.5	30.6	30.7
10	31.3	0.5	26.3	28.8	29.6	30.1	30.3	30.5	30.6	30.7
11	30.6	0.2	28.6	29.6	29.9	30.1	30.2	30.3	30.3	30.4
12	30.2	0.1	29.2	29.7	29.9	30.0	30	30.0	30.1	30.1
Avg.	30.8	0.3	27.7	29.3	29.8	30.1	30.2	30.3	30.4	30.4

Table 5. Mean hourly comfort temperature according to the Griffiths method.

Hour	$T_{i(mean)}$	$VASH_{(mean)}$	***a* = 0.1**	***a* = 0.2**	***a* = 0.3**	***a* = 0.4**	***a* = 0.5**	***a* = 0.6**	***a* = 0.7**	***a* = 0.8**
10	30.1	−0.1	31.1	30.6	30.4	30.4	30.3	30.3	30.2	30.2
11	30.2	0.1	29.2	29.7	29.9	30.0	30	30.0	30.1	30.1
12	30.9	0.4	26.9	28.9	29.6	29.9	30.1	30.2	30.3	30.4
13	31.1	0.2	29.1	30.1	30.4	30.6	30.7	30.8	30.8	30.9
14	31.4	0.5	26.4	28.9	29.7	30.2	30.4	30.6	30.7	30.8
15	31.1	0.4	27.1	29.1	29.8	30.1	30.3	30.4	30.5	30.6
16	31.4	0.6	25.4	28.4	29.4	29.9	30.2	30.4	30.5	30.7
17	31	0.4	27	29	29.7	30.0	30.2	30.3	30.4	30.5
18	30.4	0.2	28.4	29.4	29.7	29.9	30	30.1	30.1	30.2
19	30.1	0.1	29.1	29.6	29.8	29.9	29.9	29.9	30.0	30.0
Avg.	30.6	0.2	29.1	29.9	30.1	30.3	30.3	30.4	30.4	30.4

4. Conclusions

This study is about exploring hourly and monthly thermal comfort in the humid tropics of Malaysia. The results and discussion lead to the following conclusions:

The analysis of climatic data revealed that the outdoor monthly mean temperature range was narrower than the hourly mean temperature range.

No seasonal differences were found in neutral temperature predictions. The predicted indoor neutral temperature during the wet season was 30.2 ± 0.2 °C. The predicted indoor neutral temperature during the dry season was 30.0 ± 0.3 °C. The results were close to the mean neutral temperatures. However, the data revealed that occupants' thermal perception changed slightly with the variation of the hourly indoor air temperature.

The mean neutral temperature estimated from the mean monthly indoor air temperatures was 30.1 ± 0.1 °C. The mean indoor neutral temperature estimated from the mean hourly indoor air temperatures (9 a.m. to 7 p.m.) was 30.3 ± 0.2 °C.

The Griffiths method was explored and applied for the prediction of hourly and monthly neutral temperatures. Further field investigations were recommended to validate the results. This is because The Griffiths method might not provide accurate results. It was also highly advised to carry out further investigations, specifically during nighttime and early morning in residential wooden houses. This is because the variation in hourly neutral temperature is likely to be observed during that time.

Acknowledgments

The Kota Kinabalu climatic data were collected from Sabah and Malaysian meteorological departments.

Author Contributions

Harimi Djamila designed the study, performed the analysis and wrote the manuscript. Chu Chi Ming and Sivakumar Kumaresan critically evaluated the study and helped in editing the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Simon, B.; Elaine, M.T.; Rachel, M.G.; Christos, A.; Shoji, S. All in good time: The Arabidopsis circadian clock. *Trends Plant Sci.* **2000**, *5*, 517–522.
2. Shukuya, M. The circulation of matter and energy. In *Architecture for a Sustainable Future*; Murakami, S., Eds.; Architectural Institute of Japan: Tokyo, Japan, 2005; pp. 35–38.
3. Newsham, G.R.; Tiller, D.K. *A Field Study of Office Thermal Comfort Using Questionnaire Software*; IRC Internal Report 708; Institute for Research in Construction: Ottawa, ON, Canada, 1995.
4. Karyono, T.H. Report on thermal comfort and building energy studies in Jakarta-Indonesia. *Build. Environ.* **2000**, *35*, 77–90.

5. Fanger, P.O. *Thermal Comfort: Analysis and Applications in Environmental Engineering*; McGraw-Hill: New York, NY, USA, 1972.
6. Heerwagen, D. *Passive and Active Environmental Controls*; McGraw-Hill: New York, NY, USA, 2004.
7. Harimi, D. Roofing Specifications in Sabah: Assessment of Thermal Performance. Master's Thesis, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia, 2005.
8. Harimi, D.; Chi, C.; Sivakumar, K. An Analysis of the effects of occupants' perceptions of their indoor environment on their assessments of their thermal sensation and comfort. *Adv. Environ. Biol.* **2014**, *8*, 231–237.
9. Teli, D.; Jentsch, M.F.; James, P.A.B. The role of a building's thermal properties on pupils' thermal comfort in junior school classrooms as determined in field studies. *Build. Environ.* **2014**, *82*, 640–654.
10. Gabri, N.M.S. Thermal Comfort and Building Design Strategies for Low Energy Houses in Libya: Lessons from the vernacular architecture. Ph.D. Thesis, University of Westminster, London, UK, July 2014.
11. Rijal, H.B. Field Investigation of Comfort Temperature and Adaptive Model in Japanese Houses. In Proceedings of PLEA 2013, Munich, Germany, 10–12 September 2013.
12. McCartney, K.J; Nicol, J.F. Developing an Adaptive Control Algorithm for Europe. *Energy Build.* **2002**, *34*, 623–635.
13. Nicol, F.; Humphreys, M.; Roaf, S. *Adaptive Thermal Comfort: Principles and Practice*; Routledge: London, UK, 2012.
14. Honjo, M.; Rijal, H.B.; Kobayashi, R.; Nakaya, T. Investigation of comfort temperature and the adaptive model in Japanese houses. In Proceedings of the 7th Windsor Conference: The Changing Context of Comfort in an Unpredictable Word, Windsor, UK, 12–15 April 2012.
15. Humphreys, M.; Nicol, F.; Iftikhar, A.R. Field studies of indoor thermal comfort and the progress of the adaptive approach. *Adv. Build. Energy Res.* **2007**, *1*, 55–88.
16. Toe, D.H.C.; Kubota, T. Development of an adaptive thermal comfort equation for naturally ventilated buildings in hot–humid climates using ASHRAE RP-884 database. *Front. Archit. Res.* **2013**, *2*, 278–291.
17. Chapra, S.C.; Canale, R.P. *Numerical Methods of Engineers*, 6th ed.; McGraw Hill: Boston, MA, USA, 2010.
18. Nguyen, A.T.; Singh, M.K.; Reiter, S. An adaptive thermal comfort model for hot humid South-East Asia. *Build. Environ.* **2012**, *56*, 291–300.