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Comfort Temperature for Different Gender: Case Study in UTHM Lecture Room

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Abstract: The objective of this study is to determine the comfort temperature for different gender based on UTHM case study. The comfort temperature is determined based on Predicted Mean Vote (PMV) index by using regression analysis. In this study, there are two methods that are used to determine the PMV index, namely physical measurement method and human response method. Physical measurement method is used by measuring the environment inside the lecture room around UTHM, while human response method is used by conducting a survey when lecture is in progress. There are six parameters involved in this study, namely air temperature, mean radiant temperature, air velocity, relative humidity, metabolic rate and clothing insulation. The measuring instruments used in this study are VelociCalc® Plus device and KIMO® AMI 310 device, and the data collection time is from around 8 a.m. to 6 p.m. The data collection consists of 10 samples with different environmental conditions. Based on the results obtained from PMV linear regression analysis, the comfort temperature range for male is from 24.5 °C to 27.1 °C, while the comfort temperature range for female is from 25.4 °C to 27.5 °C through physical measurement. Besides, the comfort temperature range for male is from 25.1 °C to 26.5 °C, while the comfort temperature range for female is from 25.3 °C to 26.9 °C through human response. This statement shows that the comfort temperature for female is higher than the comfort temperature for male because females prefer higher room temperatures than males.

Keywords: Thermal Comfort, Gender, PMV, Correlation and Regression

1. Introduction

A good Indoor Air Quality (IAQ) is important for a healthy indoor environment to improve the thermal comfort level. This ensures better health, comfort and productivity. Nowadays, many people spent most of their time in an artificial climate. To achieve these requirements, the thermal environment for a space needs to be comfortable to ensure an effective IAQ in the space. The comfortable thermal environment can be determined by Predicted Mean Vote (PMV) as the thermal comfort level can affect individual health and performance. Due to large variations in characteristics of person, it is difficult to satisfy everyone because the environmental conditions required for thermal comfort are different for everyone. Therefore, extensive laboratory and field data have been collected to determine the space comfort temperature for the occupants [1].

For thermal environment evaluation, Fanger [2] developed the PMV model involving four environmental factors namely air temperature, mean radiant temperature, relative humidity, and air velocity, as well as two human body factors namely clothing and activity or metabolic rate. The metabolic rate is different for everyone, even though people are at the same activity level [3]. An observation states that gender is one of the factors that must be considered in the thermal comfort assessment [4]. Therefore, the comfort temperatures with both genders are determined in this study.

According to a study [5], the values of standard for one of its main variables are metabolic rate, which are based on an average male, and this may overestimate the metabolic rate for female by up to 35 %. Generally, females prefer higher ambient temperature than males in home and office situations, and the difference in mean values is found to be 3K, where males prefer a mean temperature of 22 °C whereas females prefer a mean

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temperature of 25 °C [6]. Another study [7] also claimed that females prefer a higher ambient temperature compared to males. This implies that there is a significant difference in comfort temperature range between male and female people.

2. Methodology

In this section, the methodology is generally divided into two main categories, which are physical measurement and human response. The data is analyzed by comparison of temperature and PMV relationships by using regression method and the comfort temperature range for both genders are determined. The methodology of the study is illustrated by using a flow chart as shown in Fig. 1.

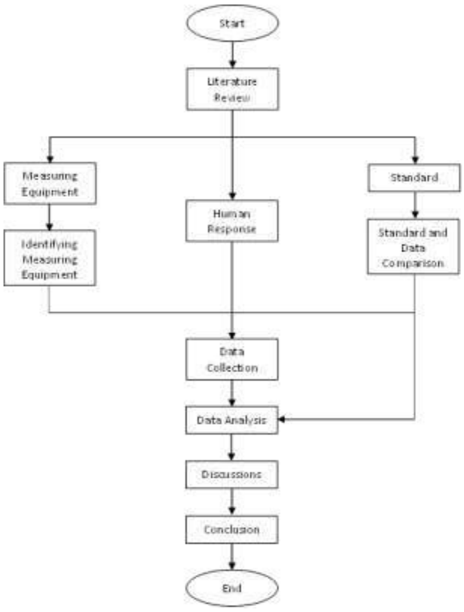

Fig. 1 – Methodology flow chart

2.1 Physical Measurement

VelociCalc® Plus Model 8386 and KIMO® AMI 310 are the measurement devices used to measure the parameters involved in this study as shown in Fig. 2. The physical measurement is made inside the lecture room during the progression of the lecture, and the time for the measurement is from around 8 a.m. to 6 p.m.

Fig. 2 – VelociCalc® Plus and KIMO® AMI 310

2.2 Human Response

A survey is used to measure the sensation of occupants towards thermal environment based on the seven-point scale [1], where +3 = hot, +2 = warm, +1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool, and -3 = cold. The survey is conducted at the same time with the physical measurement. The survey questionnaires shown in Fig. 3 are distributed an hour after the lecture begins.

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SURVEY OF COMFORT LEVEL AT UTHM LECTURE ROOM

Dear Respondents,

The purpose of this survey is to analyze the feedback of **Effect of Gender On Human Comfort** based on human response. I would love to hear your thoughts and honest response on this survey so that comfort level can be determined. Your response on this survey will be highly appreciated. Thank you.

FILLED IN BY OCCUPANT:

1. Occupant's Name :
2. Matric No. :
3. Date :
4. Time :
5. Occupant's Clothing:

Clothing		Please Tick (√)
Shirts	Short Sleeves	
	Long Sleeves	
	Hijab	
Sweaters	Long-sleeve (thin)	
	Long-sleeve (thick)	
Trousers	Straight trousers (thin)	
	Straight trousers/Jeans (thick)	
Footwear	Normal Socks	
	Ankle length socks	
	Shoes / Sandals	
	Slippers	

6. Health Condition (Please Tick √)

Healthy		Fever		Influence of Alcohol	

7. At this surrounding condition, what can you feel right now? (Please Tick √)

Hot	Warm	Slightly Warm	Neutral	Slightly Cool	Cool	Cold

Fig. 3 – Questionnaire for human response

2.3 Regression

The PMV values are analyzed for comparison with the relationships between both genders by using regression method to predict the comfort temperature range for both genders. The regression is done by using Microsoft Excel. Through regression analysis, the relationship between temperature and PMV is obtained and the respective equations are developed based on the relationship obtained. Finally, the comfort temperature range is determined, where minimum and maximum comfort temperature can be obtained when PMV values are −0.5 and 0.5 respectively. Meanwhile, the neutral comfort temperature can be also determined when the PMV value is zero.

3. Results and Discussion

This section consists of data analysis and discussion on this study. All the data collected is shown in detail in tables and graphs. The physical measurement data and the human response data are analyzed and discussed in this section. However, due to the situation of COVID-19 pandemic, the raw data from the previous study [8] is used as the data collection in this study since the physical data collection is not be able to carry out.

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3.1 Data Analysis

Table 1 shows the data collection for the physical measurement. All the parameters are taken by using the measuring equipment, except for metabolic rate and clothing insulation values. The physical data collection is carried out and 10 samples are collected. For the entire samples that are collected, the clothing insulation values used for male and female are 0.49 clo and 0.54 clo respectively, and the metabolic rate values used for male and female are 1.0 met and 0.9 met respectively [8].

Table 1 – Data for physical measurement

No	Gender *M – Male, F - Female*	Cloth Insulation (clo)	Air Temperature (ºC)	Mean Radian Temperature (ºC)	Metabolic Rate (met)	Air Velocity (m/s)	Relative Humidity (%)	PMV
	Parameter							
1	M	0.49	25.0	25.1	1.0	0.14	73.2	-0.23
	F	0.54			0.9			-0.59
2	M	0.49	25.5	25.1	1.0	0.16	71.9	-0.22
	F	0.54			0.9			-0.57
3	M	0.49	24.3	24.2	1.0	0.14	75.8	-0.51
	F	0.54			0.9			-0.90
4	M	0.49	25.6	25.5	1.0	0.13	78.1	-0.03
	F	0.54			0.9			-0.32
5	M	0.49	26.5	26.4	1.0	0.23	63.5	-0.10
	F	0.54			0.9			-0.41
6	M	0.49	25.5	25.2	1.0	0.39	75.9	-0.69
	F	0.54			0.9			-1.05
7	M	0.49	24.9	25.0	1.0	0.16	74.1	-0.34
	F	0.54			0.9			-0.71
8	M	0.49	24.9	25.0	1.0	0.18	76.1	-0.40
	F	0.54			0.9			-0.78
9	M	0.49	26.3	26.1	1.0	0.19	63.1	-0.07
	F	0.54			0.9			-0.40
10	M	0.49	25.3	25.3	1.0	0.14	76.3	-0.10
	F	0.54			0.9			-0.46

For air temperature and mean radiant temperature, the fifth sample is the highest while the third sample is the lowest. For air velocity, the sixth sample is the highest while the fourth sample is the lowest. For relative humidity, the highest is the fourth sample while the lowest is the ninth sample. Table 2 shows the data collection for human response. There are 10 samples collected for human response. The number of respondents for male and female is the same for all the samples collected.

Table 2 – Data for human response

No.	Gender	Number of Respondent	PMV Ratings with Number of Votes -3	-2	-1	0	1	2	3	PMV
1	Male	13	-	-	10	3	-	-	-	-0.77
	Female	13	-	-	5	8	-	-	-	-0.38
2	Male	13	-	-	3	10	-	-	-	-0.23
	Female	13	-	-	5	8	-	-	-	-0.38
3	Male	12	-	-	7	5	-	-	-	-0.58
	Female	12	-	-	8	4	-	-	-	-0.67
4	Male	12	-	-	2	10	-	-	-	-0.17
	Female	12	-	-	3	9	-	-	-	-0.25
5	Male	14	-	-	2	12	-	-	-	-0.14
	Female	14	-	-	6	8	-	-	-	-0.43
6	Male	14	-	-	11	3	-	-	-	-0.79
	Female	14	-	1	13	-	-	-	-	-1.07
7	Male	14	-	-	9	5	-	-	-	-0.64
	Female	14	-	-	11	3	-	-	-	-0.79
8	Male	14	-	-	7	7	-	-	-	-0.50
	Female	14	-	-	12	2	-	-	-	-0.86
9	Male	14	-	-	2	12	-	-	-	-0.14
	Female	14	-	-	7	7	-	-	-	-0.50
10	Male	14	-	-	3	11	-	-	-	-0.21
	Female	14	-	-	9	5	-	-	-	-0.64

3.2 Comparison of PMV rating

Based on the data, the PMV ratings are illustrated in bar chart as shown in Fig. 4 and 5.

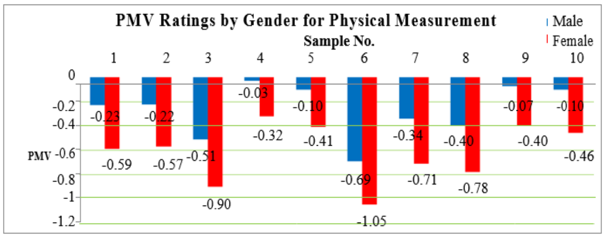

Fig. 4 – PMV ratings by gender for physical measurement

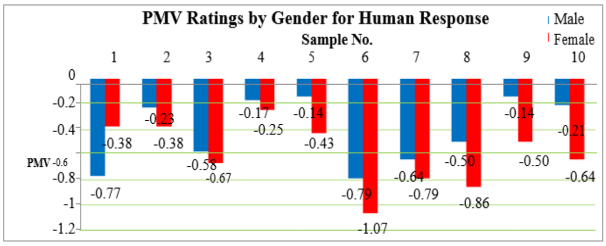

Fig. 5 – PMV ratings by gender for human response

Fig. 4 shows the PMV ratings for physical measurement. From Figure 4, male has higher PMV ratings than female for all samples. The fourth sample shows the highest PMV values while the sixth sample shows the lowest PMV values. Fig. 5 shows the PMV ratings for human response. From Fig. 5, male has higher PMV ratings than female for nine of the samples except for the first sample.

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3.3 Prediction of Comfort Temperatures

Among all possible regressions, linear regression is the most applicable to estimate comfort temperature [9, 10, 11], so linear regression best describes the relationship. However, the coefficient of determination is below 0.5, so prediction is unsuccessful [12]. After that, the third, fifth, sixth and ninth samples do not fit the graph well, as they do not link with the relationship compared to other samples. This affects coefficient of determination. Thus, four samples are removed from the analysis. The air temperature and PMV relationships are shown in Fig. 6 to Fig. 9.

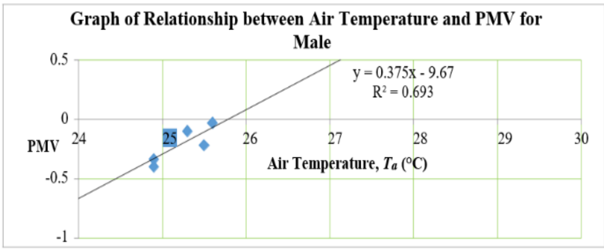

Fig. 6 – Relationship between Air Temperature and PMV for Male by Physical Measurement

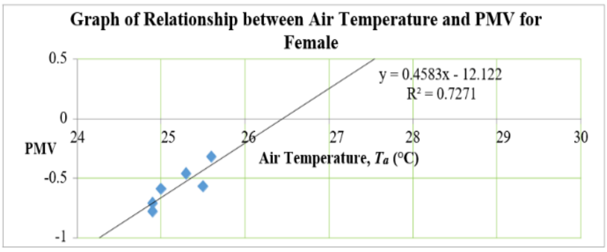

Fig. 7 – Relationship between Air Temperature and PMV for Female by Physical Measurement

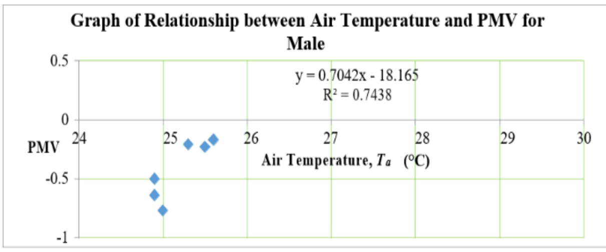

Fig. 8 – Relationship between Air Temperature and PMV for Male by Human Response

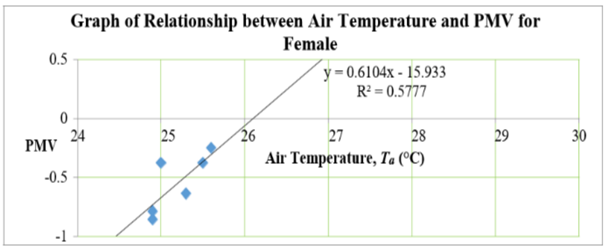

Fig. 9 – Relationship between Air Temperature and PMV for Female by Human Response

After the data adjustment is made, the coefficient of determination has been above 0.5. Hence, the comfort temperature range is determined based on Fig. 6 to Fig. 9. The minimum, maximum and neutral comfort temperatures are found when PMV values are -0.5, 0.5 and 0 respectively. The comfort temperature range and values by gender are shown in Table 3.

Table 3 – Comfort Temperature Range and Values by Gender

Method	Physical Measurement *(M – Male, F – Female)*			
Gender	M	F	M	F
Min. comfort temperature (°C)	24.5	25.4	25.1	25.3
Max. comfort temperature (°C)	27.1	27.5	26.5	26.9
Neutral comfort temperature (°C)	25.8	26.4	25.8	26.1
Comfort temperature range (°C)	24.5 ~ 27.1	25.4 ~ 27.5	25.1 ~ 26.5	25.3 ~ 26.9

3.4 Discussion

Throughout this study, 10 data samples are collected. However, due to limited availability, only 10 samples are successfully obtained. From the result obtained by human response, the PMV rating by male is lower than that by female for the first sample due to lack of understanding on sensation scale towards thermal environment, and some respondents do not respond to the questionnaire seriously.

Four data samples are removed from analysis as coefficient of determination should be above 0.5 [13]. The air velocity for sixth sample is much greater than others from Table 1 due to measurement errors, which is one of the limitations of regression analysis [14]. Others are due to inaccurate survey results, as PMV values for fifth and ninth samples are too low for high air temperatures, and PMV value for third sample is too high for low air temperature from human response by female.

From the results, male has generally higher PMV ratings than female because male has warmer thermal sensation than female. Therefore, females prefer higher room temperatures and are less satisfied with room temperatures than males [15, 16], as females will feel cold more easily. With higher metabolic rate, people are less thermally sensitive and have lower risk of local discomfort. Thus, males have lower thermal dissatisfaction than females as male has higher metabolic rate. In the contrary, the clothing insulation can be adjusted easily so that the thermal dissatisfaction can be eliminated [17].

From Fig. 6 and Fig. 7, male shows lower regression slope value than female. Since the slope value can predict the sensitivity to thermal environments [18], females are more sensitive to temperature than males [15, 19]. Also, female shows greater coefficient of determination than male, so the comfort temperature prediction is more reliable for female compared to male [20].

From Table 3, female has higher comfort temperatures than male. This is evident [7, 16, 21] when females prefer higher ambient temperatures than males. The comfort temperature ranges for male and female are from 24.5 °C to 27.1 °C, and from 25.4 °C to 27.5 °C respectively for physical measurement, and also from 25.1 °C to 26.5 °C, and from 25.3 °C to 26.9 °C respectively for human response. This complies with Malaysian Standard 1525 for indoor conditions of an air-conditioned space for minimum air temperature, where the minimum air temperature required is 23 °C [22]. PMV regression equations are shown in Table 4 with previous studies. The coefficient of determination, neutral comfort temperature and comfort temperature range are listed in Table 4.

Table 4 – PMV Regression Equations of Previous Studies

Studies	PMV Regression equation	R^2	Neutral comfort temp. (°C)	Comfort temp. range (°C)
[23]	$0.487T_a - 12.20$	0.951	25	24.0 ~ 26.1
[18]	$0.231T_a - 5.562$	0.85	24.1	21.9 ~ 26.2
[24]	$0.1472T_a - 2.615$	0.984	17.76	14.4 ~ 21.2
[25]	$0.2133T_a - 5.4358$	0.916	25.5	23.1 ~ 27.8
[26]	$0.2212T_a - 5.1563$	0.919	23.31	21.0 ~ 25.6
Current (Physical measurement)	$0.375T_a - 9.67$ (male) $0.4583T_a - 12.122$ (female)	0.693	25.8	24.5 ~ 27.1
Current (Human response)	$0.7042T_a - 18.165$ (male) $0.6104T_a - 15.933$ (female)	0.727	26.4	25.4 ~ 27.5

Generally, comfort temperature range by human response is within that by physical measurement, and physical measurement has almost the same neutral comfort temperature as human response. However, physical measurement has lower regression slope value than human response. This means that the physical measurement has lower sensitivity to thermal environments than human response. A similar study [23] is also conducted in Malaysia. The comfort temperature range is from 24 °C to 26.1 °C, which is nearly the same as the air temperature range from Malaysian Standard 1525 [22]. The regression slope value [23] is almost the same as current study but higher than other studies. So, the comfort temperature range [23] is smaller due to higher sensitivity to thermal environments [18].

For comparison with thermal comfort studies in Singapore [27], there are generally no significant differences in neutral temperatures and temperature ranges in this study because cold discomfort rarely occurred in tropical climate which is different from climate context in cold countries [27]. A study [24] on thermal comfort in cold rural areas is conducted in China. The neutral comfort temperature of 17.76 °C and comfort temperature range from 14.4 °C to 21.2 °C are lower compared to other studies due to cold climate context in China. Hence, different climate context will have different comfort temperature, where the comfort temperature will be lower in cold countries [27].

4. Conclusion

For physical measurement, the male and female comfort temperature ranges are from 24.5 °C to 27.1 °C and from 25.4 °C to 27.5 °C respectively. For human response, the male and female comfort temperature ranges are from 25.1 °C to 26.5 °C and from 25.3 °C to 26.9 °C respectively. Female has higher comfort temperature than male as females prefer higher ambient temperatures than males, but the comfort temperature can depend on sensitivity to thermal environments, and climate change. Although the sensitivity to thermal environments depends on clothing, activity, and metabolic rate, it can be predicted by using the slope of linear regression. The comfort temperatures may be varied depending on personal factors and climate change. For future studies, it is recommended to determine the thermal sensitivity of occupants in different buildings and study the difference in comfort temperature with different clothing, activity or metabolic rate, age, and with climate change.

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