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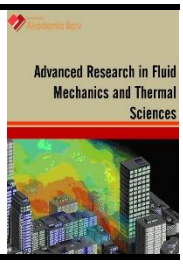

Outdoor Thermal Comfort Study of an Urban University Campus in Malaysia

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ABSTRACT

Thermal comfort is an important parameter in determining the pedestrian satisfaction dealing with daily routine activities in the outdoor environment. Therefore, the objective of this study is to investigate the outdoor thermal comfort of an urban university campus in Kuala Lumpur, Malaysia. Thermal comfort assessment is done by the field measurement and survey for different physical activities such as sitting, walking, and standing at the outdoor and semi-outdoor condition. This study was carried out from March to May 2017 during the daytime at seven zones that being most attracted gathering places for the on-campus students. The zones represent the locations of the field measurement. The thermal sensation results shown that most of the respondents voted for slightly warm (28–34%) and warm (29–34%) for the outdoor condition and 13–15% and 35–36% voted for slightly warm and warm respectively for the semi-outdoor condition. The respondents' thermal comfort for the semi-outdoor condition were improved where the respondents voted for slightly cool (19–21%) and yet no respondent voted the very hot scale for the outdoor condition. In term of the thermal acceptance, 38–42% and 47–51% voted the acceptable scale for the outdoor and semi-outdoor conditions respectively. As for the thermal preference, 35–36% and 33–34% prefer slightly cooler and cool considerably for the outdoor condition. While for the semi-outdoor condition, 47–52% and 17–20% prefer slightly cooler and cool considerably respectively. In general, the overall comfort of the respondents were neutral with 54–62% and 79–81% for the outdoor and semi-outdoor conditions respectively. In conclusion, this study proved that the occupants who live in a hot and humid climate specifically within a build-up area were adapted to and comfort with the higher temperature humidity level.

Keywords:
Thermal comfort; urban; sensation; acceptance; preference

1. Introduction

Nowadays, the rapid increase in the earth surface temperature due to increase in the energy consumption and carbon dioxide (CO_2) emission in the city. This problem is rising in the cities since many of the world's urbanizations are taking place in the tropics. Thus, it is being a crucial demand

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of the outdoor thermal comfort for the people living in the cities. Many previous studies [1–7] have been done in understanding the human thermal comfort in the different outdoor spaces under a wide range of climatic condition. However, lack of significant studies observed on the outdoor [8–11] than indoor [12–17] human thermal comfort for the tropical regions since these regions focus more on the economic growth. As instant, Yang *et al.,* [10] had reported the inhabitants in Singapore able to tolerate with the outdoor microclimatic condition ranged from 26-32°C as an acceptable temperature range for the shaded condition of resting places. The studies were conducted at 13 different areas that represent different microclimatic conditions, functions and locations of the urban area. It included the physical measurement and subjective assessment at the outdoor spaces. In contrast, Makaremi *et al.,* [8] conducted the physical measurement and subjective assessment at the outdoor spaces specifically for the shaded area. The study was conducted at two areas i.e. central of courtyard that encompass of two spaces each. The study pointed out that the physiological equivalent temperature (*PET*) under a shaded condition was higher than the comfort range (*PET*< 30 °C) and the acceptable conditions (*PET*< 34 °C) that only existed on early of a morning and late afternoon. Besides, Nasir *et al.,* [11] had revealed that the respondents are physiologically and psychologically adapted to the higher temperature range with 21-39°C than comfortable temperature range with 18-23°C in the temperate regions based on physical measurement and subjective measurement at an outdoor park. Yet, for further research, wider sampling is proposed to determine the adaptations of subjects to the microclimate [9, 10]. According to the aforementioned studies, the information on the outdoor human comfort in tropical emerging countries is still less and need to be explored. Therefore, the comprehensive field survey of the outdoor thermal comfort was conducted in an urban university campus in Kuala Lumpur, Malaysia. We are aiming to determine the outdoor thermal comfort for various outdoor activities listed as sitting, walking, and standing. It considered the outdoor and semi-outdoor conditions with wider sampling.

2. Methodology

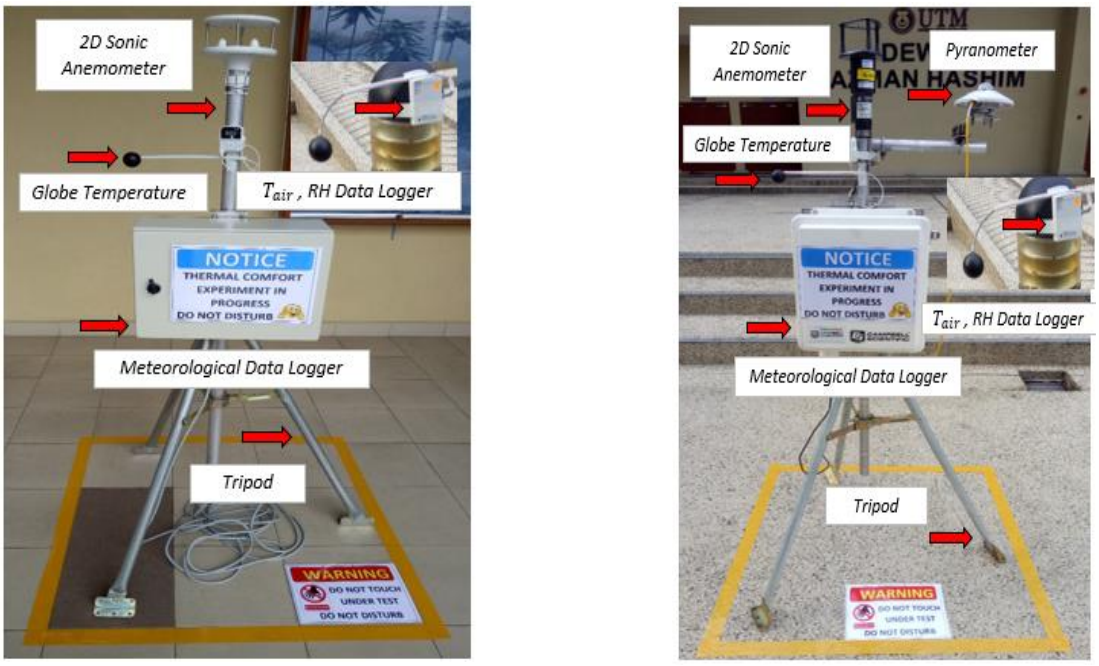
2.1 Site Description

This present study was conducted at Universiti Teknologi Malaysia Kuala Lumpur (UTMKL) which its coordinate located at 3°8'20.41"N and 101°41'12.68"E with the total area of 192,468 m^2. Seven different zones based on the most visited places by the pedestrian were selected for the measurement purposes as shown in Figure 1. Each measurement zones consist of the outdoor and semi-outdoor conditions. The outdoor condition is typically referred to a measurement directly under the sun. In contrast, the semi-outdoor condition is referred to the place that fully covered on its top such as a pedestrian walkway, canopy, pergola and building shaded. The first zone is an open space surrounded by various types of vegetation that received direct sun light and reflect the solar radiation from the nearest high-rise building. The second zone is located at the highest office building with 83 m height that surrounded with various types of vegetation and a water body section. The third, fifth and sixth zone are the open space areas with shaded waiting areas and minimal vegetation. In contrast, the forth zone that dims under the trees for the un-shaded condition with less solar penetration. The seventh zone is a high-rise residence that surrounded with other low-rise residences that received a direct solar radiation and the reflection of the solar radiation from the surrounding high-rise buildings.

Fig. 1. Seven field measurement zones in Universiti Teknologi Malaysia Kuala Lumpur. (Numeric refer to the seven different zones)

2.1 Data Collection

A series of measurement campaigns were performed from 9:00 am to 16:00 pm between February to May 2017. The micro-climatic monitored on the basis of zone by zone due to the instruments limitation. Each measurement zone takes about 3 to4 days of completion. This field study conducted for the different physical activities such as sitting, walking and standing under two different conditions i.e. outdoor and semi-outdoor for each zones. Two mobile stations were installed simultaneously for both outdoor and semi-outdoor areas. The first station was placed at the semi-outdoor condition and equipped with the HOBO U-series data logger and thermistor thermo recorder (TnD5i) sensor to measure the air temperature (T_a), globe temperature (T_g), and relative humidity (*RH*). The globe temperature is measured with an external temperature sensor (TMC1-HD) with a black painted table tennis ball of 40 mm in diameter. The wind speed (*WS*) and wind direction (*WD*) are recorded using the 2D Ultrasonic Anemometer (Delta Ohm HD32TML) data logger. Meanwhile, the second station was placed for the outdoor condition and equipped with the same instrument except for the wind speed and wind direction. The 2D Ultrasonic Anemometer (RM Young 86000) data logger installed for the wind speed and wind direction while the pyranometer (Kipp and Zenon) used to measure the solar radiation (*SR*). All devices and sensors complied with the ISO 7726 standard [18] and all parameters were continuously measured at one minute time interval. Specifically, the instruments were placed at a specific 1.1 m height above ground level and the distance between the outdoor and semi-outdoor conditions were within 3 m radius. The instruments setup described above are shown in Figure 2 with the detail specifications of the instruments presented in Table 1.



(a) (b)

Fig. 2. Measurement instruments setup for the (a) semi-outdoor condition and; (b) outdoor condition

Table 1
Measured meteorological data, instruments and sensor accuracy and range

Meteorological Data	Symbol	Unit	Instrument	Accuracy	Range
Air temperature	T_a	°C	HOBO U-series and thermistor thermometer (TR-52i) data logger	± 0.35 °C from 0 to 50 °C and ± 0 °C from 0 to 50 °C	-20 to 70 °C and -40 to 80 °C
Globe temperature	T_g	°C	HOBO U-series and thermistor thermometer (TR-52i) Data Logger	± 0.35 °C from 0 to 50 °C and ± 0.5 °C from 0 to 50 °C	-20 to 70 °C and -40 to 80°C
Wind speed (Outdoor)	*WS*	m/s	2D Ultrasonic Anemometer – RM Young 86000	±0.1 m/s (30 m/s), ±3% (70 m/s)	0 to 70 m/s
Wind speed (Semi-outdoor)	*WS*	m/s	2D Ultrasonic Anemometer – Delta Ohm	± %, ±0.1 m/s (30 m/s), ±3% (60m/s)	0 to 60 m/s
Relative humidity	*RH*	%	HOBO U-series data logger	± 2.5% from 10% to 90% RH	5% to 95% RH
Solar radiation	*SR*	W/m²	PyranomterKipp&Zenon (LP PYRA0.8BL)	7 to 14 µV/W/m²	≤4000 W/m²

2.3 Outdoor Thermal Comfort Survey

A total number of 3024 questionnaires were completed from 507 students for the seven zones. This survey conducted for three physical activities and two conditions. In total, approximately 81% of the respondents were males and 19% were females at the age range from 18 to 22 years old. The survey form was distributed simultaneously to the volunteered university students during the period of measurement. Each participant needs to do three physical activities that are sitting, walking and standing for the outdoor and semi-outdoor conditions. Each activity consumed about 15 minutes for the adapting time exposure and five minutes for answering the survey form. Each participant spend about two hours to complete all physical activities for both conditions. The questionnaires consisted of three sections. The first section is about the demographic. The second section listed the question

on the subject's sensation, acceptance, and preference, 15 minutes past activity and also the subject's countermeasure such as find a sunshade area, wearing an umbrella, wearing cap and etc. Moreover, respondents clothing insulation were also surveyed through the questionnaires based on the clothing items worn during the measurement from undergarment, socks, shoes, top, and bottom based on ASHRAE [19] clothing insulation value in the third section. The evaluation is based on 9-point scales for the thermal sensation and 5-point scales for the thermal acceptance, preference and overall comfort as shown in Table 2.

Table1
Thermal sensation, acceptance preference and overall comfort for outdoor thermal comfort scales

Parameters	Scales	Thermal Sensation (*TSV*)	Thermal Acceptance (*TAV*)	Thermal Preference (*TPV*)	Overall Comfort (*OC*)
Thermal	4	Very hot			
	3	Hot			
	2	Warm	Very uncomfortable	Cooler considerably	Very uncomfortable
	1	Slightly warm	Uncomfortable	Slightly cooler	Uncomfortable
	0	Neutral	Acceptable	No change	Acceptable
	-1	Slightly cool	Comfortable	Slightly warmer	Comfortable
	-2	Cool	Very comfortable	Warmer considerably	Very comfortable
	-3	Cold			
	-4	Very cold			

Note - *TSV*: thermal sensation vote, *TAV*: thermal acceptance vote, *TPV*: thermal preference vote, *OC*: Overall comfort

2.3 Thermal Comfort Index

In this studies, *PET* index was used to measure the comfort thermal since it takes into account on both microclimates measurement (T_a,T_g, *RH*, *WS*, *SR*) and human subject based on a questionnaire survey of sensation, acceptance, and preference. In this study, *PET* was calculated from the aforementioned parameters using the RayMan software [20–22].

3. Results

3.1 Outdoor Climatic Parameters Monitored

Table 3 summarises the mean and standard deviation (S.D.) of the T_a, T_g, *RH*, *WS,* and *SR* for the outdoor and semi-outdoor conditions of all zones during the period of measurement. The temperature and relative humidity range from 30°C to 36°C and 50% to 61% for the outdoor condition whereas 28°C to 31°C and 60% to 73% for the semi-outdoor condition. The wind speed varies from zero to 2 m/s for both conditions and this might due to the vegetation and surrounding structures which blocked the wind and mitigate its speed. As for solar radiation, the range is from 40 to 1100 W/m² during sunny days at daytime. The overall weather condition during the measurement was sunny and calm.

3.2 Thermal Sensation and PET

The summary of statistical data for thermal sensation vote (*TSV*) and *PET* for the outdoor and semi-outdoor conditions at different zones are shown in Table 4. Most of the respondents voted for the neutral (0) and slightly warm (+1) scales for all activities for the semi-outdoor measurement zones. In contrast, the respondents voted the slightly warm (+1) and warm (+2) scales for the outdoor

condition. In term of *PET* index, the temperature range was approximately 35°C to 38°C and 32°C to 34 °C for the outdoor and semi-outdoor conditions respectively.

Table 3
Average and standard deviation of local meteorological data during measurement period

Zone	Outdoor					Semi-outdoor			
	T_a (°C)	RH (%)	WS (m/s)	SR (W/m²)	T_g (°C)	T_a (°C)	RH (%)	WS (m/s)	T_g (°C)
1	30.4 (1.7)	60 (6.0)	1.7 (1.3)	170 (1.3)	32.0 (2.3)	29.0 (1.3)	62 (6.0)	1.5 (1.7)	29.7 (1.3)
2	33.3 (3.3)	58 (7.0)	0.9 (0.5)	263 (1.2)	36.5 (4.3)	29.8 (1.8)	63 (7.0)	0.4 (0.3)	30.7 (2.0)
3	35.9 (3.6)	52 (10.0)	1.3 (0.4)	317 (2.5)	38.6 (5.0)	31.6 (2.0)	62 (7.0)	0.7 (0.5)	33.1 (1.8)
4	31.0 (1.3)	59 (5.0)	0.4 (0.3)	44 (0.4)	32.9 (1.5)	29.1 (1.5)	69 (6.0)	0.3 (0.2)	30 (1.7)
5	33.1 (2.1)	57 (8.0)	1.1 (0.6)	560 (1.5)	35.8 (3.9)	30.9 (1.6)	6 (7.0)	0.7 (0.4)	31.8 (1.9)
6	35.5 (3.1)	55 (10.0)	0.6 (0.3)	800 (1.2)	35.9 (3.2)	31.1 (1.5)	65 (7.0)	0.6 (0.4)	32.1 (1.6)
7	34.7 (3.7)	61 (16.0)	0.7 (0.3)	1100 (1.1)	34.9 (5.8)	28.6 (1.7)	73 (8.0)	0.7 (0.4)	28.7 (1.5)

Note – T_a: air temperature, T_g: globe temperature, *RH*: relative humidity, *WS*: wind speed, *SR*: solar radiation. Values in the bracket refer to the standard deviation.

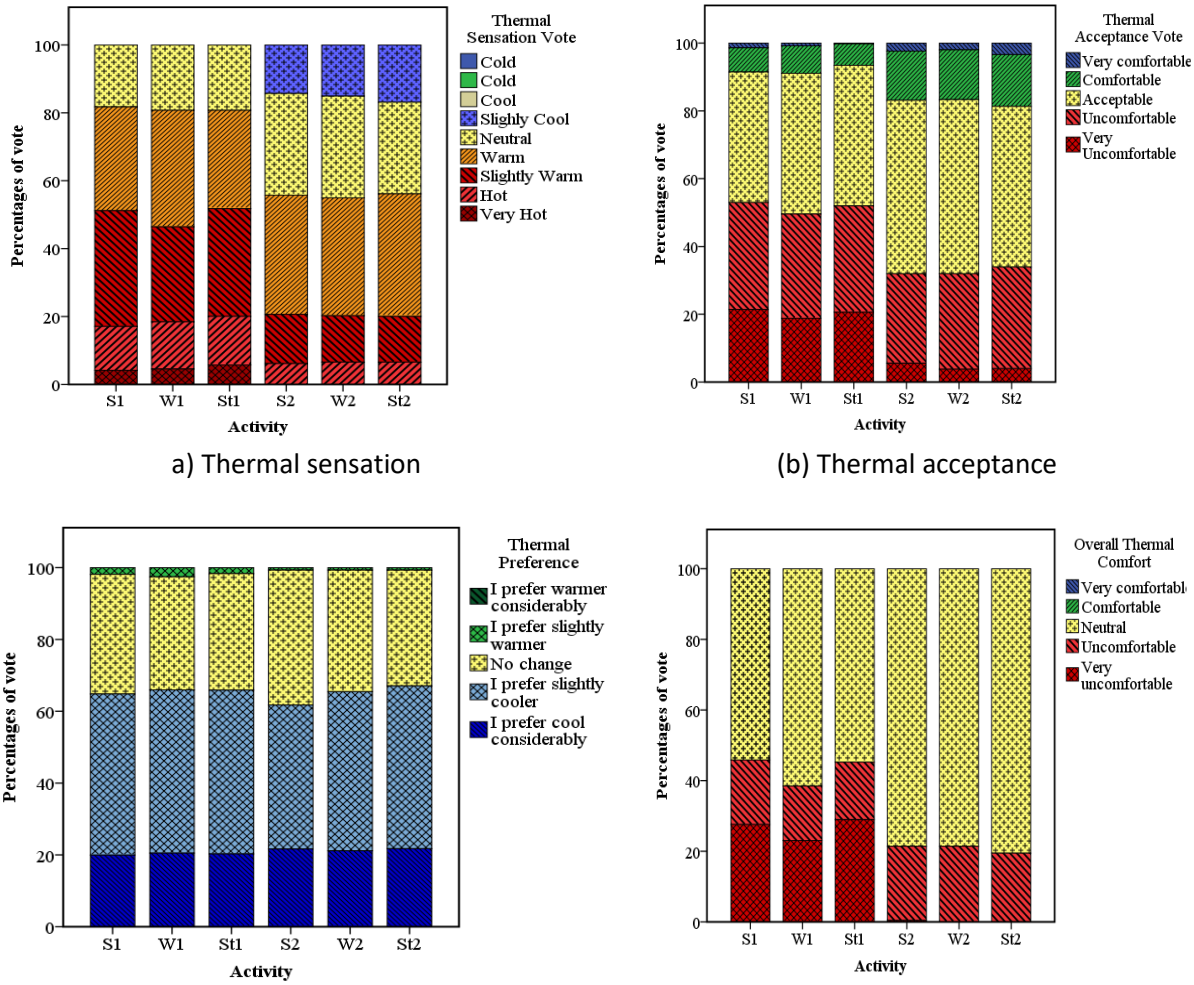
Table 4
Average and standard deviation of the *TSV* and *PET* indices for the different phyiscal activities at the outdoor and semi-outdoor conditions

Activity	Condition	Parameter	Zone						
			1	2	3	4	5	6	7
Sitting	Outdoor	*TSV*	1.41 (0.87)	1.45 (1.23)	1.68 (1.19)	1.90 (1.08)	1.31 (0.82)	1.44 (0.98)	1.60 (1.14)
		PET	35.2 (3.5)	35.8 (5.9)	37.3 (6.7)	37.9 (5.6)	35.2 (3.6)	36.0 (5.1)	36.8 (5.6)
	Semi-outdoor	*TSV*	0.47 (0.75)	0.42 (1.25)	0.99 (1.41)	0.91 (1.07)	0.53 (0.87)	0.71 (0.81)	0.74 (1.11)
		PET	32.4 (2.3)	32.0 (3.8)	34.3 (4.5)	34.0 (3.3)	32.8 (2.8)	33.0 (2.4)	33.2 (3.4)
Walking	Outdoor	*TSV*	1.44 (0.93)	1.38 (1.21)	1.58 (1.33)	1.56 (1.03)	1.51 (0.90)	1.51 (1.10)	1.53 (1.09)
		PET	35.2 (3.7)	35.6 (5.9)	36.8 (6.8)	36.5 (5.0)	35.9 (4.0)	35.9 (5.0)	36.1 (4.9)
	Semi-outdoor	*TSV*	0.47 (0.88)	0.42 (1.25)	0.97 (1.42)	0.88 (1.11)	0.58 (0.84)	0.65 (0.84)	0.68 (1.12)
		PET	32.4 (2.5)	32.3 (4.0)	34.1 (4.5)	34.1 (3.7)	32.9 (2.6)	33.0 (2.4)	33.1 (3.6)
Standing	Outdoor	*TSV*	1.67 (0.90)	1.61 (1.16)	1.71 (1.41)	1.54 (1.15)	1.51 (1.11)	1.57 (0.98)	1.49 (1.09)
		PET	36.4 (4.3)	36.7 (5.8)	36.9 (6.9)	36.8 (6.1)	36.1 (4.9)	36.7 (4.5)	36.2 (5.0)
	Semi-outdoor	*TSV*	0.63 (0.86)	0.45 (1.26)	0.81 (1.60)	0.71 (0.99)	0.56 (0.75)	0.73 (0.89)	0.71 (1.14)
		PET	32.9 (2.8)	32.2 (3.9)	33.7 (4.7)	33.6 (3.4)	32.9 (2.5)	33.0 (2.4)	33.2 (3.4)

Note – *TSV*: thermal sensation vote; *PET*: physiologically equivalent temperature. Values in the bracket refer to the standard deviation.

3.3 Thermal Sensation, Acceptance, Preference and Overall Thermal Comfort

Figure 3 illustrates the percentages of votes in term of the thermal sensation, acceptance, preference, and overall thermal comfort for the different physical activities at the outdoor and semi-outdoor conditions. For the outdoor condition, the respondents voted for the neutral (18–19%), slightly warm (28–34%), warm (29–34%), hot (13–14%) and very hot (4–6%) ranges of scale. While for the semi-outdoor condition, respondents voted for the slightly cool (14–15%), neutral (27–30%), slightly warm (13–15%), warm (35–36%) and hot (6–7%) ranges of scale. The result in Figure 3(a) shows that most of the respondents voted for the slightly warm and warm for the outdoor and semi-outdoor conditions. While for the semi-outdoor condition, the respondents' thermal comforts were improved. This is shown by the votes for the slightly cool (19–21%) chosen by the respondents. As expected, no respondent voted for the very hot scale as for the outdoor condition.



a) Thermal sensation

(b) Thermal acceptance

(c) Thermal preference

(d) Overall thermal comfort

Fig. 3. Percentages of vote for (a) thermal sensation, (b) thermal acceptance, (c) thermal preference, (d) overall thermal comfort

Figure 3(b) shows the distribution of the thermal acceptance votes, the result indicated that 38% to 42% and 47% to 51% voted for the acceptable scale for the outdoor and semi-outdoor conditions respectively. While for the thermal preference for the outdoor condition, the respondents preferred slightly cooler and cool considerably which ranges between 35% to 36% and 33% to 34% respectively. For the semi-outdoor condition, 47% to 52% and 17% to 20% preferred

slightly cooler and cool considerably as shown in Figure 3(c). In general, the respondents overall comfort was neutral with 54% to 62% and 79% to 81% for the outdoor and semi-outdoor conditions respectively as illustrated in Figure 3(d).

4. Conclusions

In this paper, the field measurements of the urban microclimatic parameters (i.e., air temperature, relative humidity, wind speed, wind direction, solar radiation) in Kuala Lumpur were measured simultaneously with the distributed questionnaires. The summary of the findings as follows.

i. For the thermal sensation, the respondents voted for neutral (18–19%), slightly warm (28–34%), warm (29–34%), hot (13–14%) and very hot (4–6%) at the outdoor condition and voted for slightly cool (14–15%), neutral (27–30%), slightly warm (13–15%), warm (35–36%) and hot (6–7%) for the semi-outdoor condition.
ii. For the thermal acceptance, 38–42% and 47–51% voted for the acceptable at the outdoor and semi-outdoor conditions respectively.
iii. For the thermal preference, 35–36% and 33–34% prefer slightly cooler and cool considerably at the outdoor condition while for the semi-outdoor condition voted for the same scale in the ranges of 47–52% and 17–20%.
iv. For the overall thermal comfort, majority of the respondents voted for the neutral scale with 54–62% and 79–81% for the outdoor and semi-outdoor conditions respectively.

In conclusion, this study shows well distributed thermal environment of the urban area in Malaysia under the outdoor and semi-outdoor conditions. These were depended on the different combination and configuration proportions of the environmental factors such as climate, environment, and vegetation which might influence the thermal perception, acceptance, and preferences among different peoples. This study helps to further understand the thermal comfort in creating a better outdoor condition for future enhancement in the hot, humid climate region.

Acknowledgments

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References

[1] Metje, N., M. Sterling, and C. J. Baker. "Pedestrian comfort using clothing values and body temperatures." *Journal of Wind Engineering and Industrial Aerodynamics* 96, no. 4 (2008): 412-435.
[2] Krüger, Eduardo, Patricia Drach, Rohinton Emmanuel, and Oscar Corbella. "Urban heat island and differences in outdoor comfort levels in Glasgow, UK." *Theoretical and Applied Climatology* 112, no. 1-2 (2013): 127-141.
[3] Salata, Ferdinando, Iacopo Golasi, Roberto de Lieto Vollaro, and Andrea de Lieto Vollaro. "Outdoor thermal comfort in the Mediterranean area. A transversal study in Rome, Italy." *Building and environment* 96 (2016): 46-61.
[4] Krüger, E., F. Rossi, and P. Drach. "Calibration of the physiological equivalent temperature index for three different climatic regions." *International journal of biometeorology* 61, no. 7 (2017): 1323-1336.
[5] Lin, Tzu-Ping. "Thermal perception, adaptation and attendance in a public square in hot and humid regions." *Building and environment* 44, no. 10 (2009): 2017-2026.
[6] Hirashima, SQ da S., Antje Katzschner, Daniele G. Ferreira, E. S. De Assis, and Lutz Katzschner. "Thermal comfort comparison and evaluation in different climates." *Urban Climate* 23 (2018): 219-230
[7] Canan, Fatih, Iacopo Golasi, Virgilio Ciancio, Massimo Coppi, and Ferdinando Salata. "Outdoor thermal comfort conditions during summer in a cold semi-arid climate. A transversal field survey in Central Anatolia (Turkey)." *Building and Environment* 148 (2019): 212-224.
[8] Makaremi, Nastaran, Elias Salleh, Mohammad Zaky Jaafar, and AmirHosein GhaffarianHoseini. "Thermal comfort

conditions of shaded outdoor spaces in hot and humid climate of Malaysia." *Building and environment* 48 (2012): 7-14.

[9] Yang, Wei, Nyuk Hien Wong, and Guoqiang Zhang. "A comparative analysis of human thermal conditions in outdoor urban spaces in the summer season in Singapore and Changsha, China." *International journal of biometeorology* 57, no. 6 (2013): 895-907.

[10] Yang, Wei, Nyuk Hien Wong, and Steve Kardinal Jusuf. "Thermal comfort in outdoor urban spaces in Singapore." *Building and Environment* 59 (2013): 426-435.

[11] Nasir, Rabiatul Adawiyah, Sabarinah Sh Ahmad, and Azni Zain Ahmed. "Physical activity and human comfort correlation in an urban park in hot and humid conditions." *Procedia-Social and Behavioral Sciences* 105 (2013): 598-609.

[12] Damiati, Siti Aisyah, Sheikh Ahmad Zaki, Hom Bahadur Rijal, and Surjamanto Wonorahardjo. "Field study on adaptive thermal comfort in office buildings in Malaysia, Indonesia, Singapore, and Japan during hot and humid season." *Building and Environment* 109 (2016): 208-223.

[13] Mustapa, Mohd Sabri, Sheikh Ahmad Zaki, Hom Bahadur Rijal, Aya Hagishima, and Mohamed Sukri Mat Ali. "Thermal comfort and occupant adaptive behaviour in Japanese university buildings with free running and cooling mode offices during summer." *Building and Environment* 105 (2016): 332-342.

[14] Mustapa, Mohd Sabri, Sheikh Ahmad Zaki Shaikh Salim, Mohamed Sukri Mat Ali, and Hom Bahadur Rijal. "Investigation of thermal comfort at different temperature settings for cooling in university building." *J. Mech. Eng.* 4, no. 4 (2017): 123-134.

[15] Zaki, Sheikh Ahmad, Siti Aisyah Damiati, Hom Bahadur Rijal, Aya Hagishima, and Azli Abd Razak. "Adaptive thermal comfort in university classrooms in Malaysia and Japan." *Building and Environment* 122 (2017): 294-306.

[16] Khalid, Waqas, Sheikh Ahmad Zaki, Hom Bahadur Rijal, and Fitri Yakub. "Thermal Comfort Requirements for Different Occupants in Malaysian Hospital In-patient Wards." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 43, no.1 (2018): 128-140.

[17] Khalid, Waqas, Sheikh Ahmad Zaki, Hom Bahadur Rijal, and Fitri Yakub. "Investigation of comfort temperature and thermal adaptation for patients and visitors in Malaysian hospitals." *Energy and Buildings* 183 (2019): 484-499.

[18] ISO (1998). "ISO 7726, Ergonomics of the Thermal Environment, Instruments for Measuring Physical Quantities," *Geneva International Standard Organization*.

[19] ASHRAE Standard (2004). "ANSI/ASHRAE 55:2004 Thermal Environmental Conditions for Human Occupancy," *Ashrae,* pp 30.

[20] Matzarakis, Andreas, Helmut Mayer, and Moses G. Iziomon. "Applications of a universal thermal index: physiological equivalent temperature." *International journal of biometeorology* 43, no. 2 (1999): 76-84.

[21] Matzarakis, A., and F. Rutz. "RayMan: a tool for tourism and applied climatology." *Development in Tourism Climatology*(2007): 129-138.

[22] Matzarakis, Andreas, Frank Rutz, and Helmut Mayer. "Modelling radiation fluxes in simple and complex environments: basics of the RayMan model." *International journal of biometeorology* 54, no. 2 (2010): 131-139.