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Procedia
Social and Behavioral Sciences

Procedia - Social and Behavioral Sciences 68 (2012) 865 – 878

AicE-Bs 2012 Cairo
ASIA Pacific International Conference on Environment-Behaviour Studies
Mercure Le Sphinx Cairo Hotel, Giza, Egypt, 31 October – 2 November 2012
"Future Communities: Socio-Cultural & Environmental Challenges"

Psychological Adaptation of Outdoor Thermal Comfort in Shaded Green Spaces in Malaysia

Rabiatul Adawiyah Nasir[a], Sabarinah Sh Ahmad[a*], Azni Zain Ahmed[b]

[a]*Faculty of Architecture, Planning and Surveying,*
[b]*Faculty of Applied Science,*
Universiti Teknologi MARA, 40450 Malaysia

Abstract

This study clarifies the perceptive and adaptive mechanisms involved in outdoor thermal comfort. The method of the study was through microclimate measurement coupled with systematic interviews of urban park users to identify the impacts of weather and personal factors on respondents' perceptual and sensation estimations. The findings on the significant influences of microclimate parameters and personal factors on the participants' perceptions of outdoor urban places are discussed. This study shows the respondents' thermal adaptation from physiological and psychological perspectives. The significance of the findings showed the importance of a sustainable urban park for continued use by future communities.

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Selection and peer-review under responsibility of the Centre for Environment-Behaviour Studies (cE-Bs), Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.

Keywords: Outdoor thermal comfort; urban park; microclimate; hot and humid

1. Introduction

Outdoor green spaces are important for a community's well-being. Parks and green spaces play a vital role to improve the health of the community and also mitigate the effects of climate change. Parks and green spaces should not only provide a place to recreate but create the opportunity of a psychological revitalization of daily life. In a prior study conducted in 1995, Nichol proved that the forested area in Singapore had a cooling effect compared with the dense city area(Nichol, 1996). This study showed that

[*] Corresponding author. Tel.: +6-012-3465788; fax: +6-035-5442096.
E-mail address: sabar643@salam.uitm.edu.my.

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Selection and peer-review under responsibility of the Centre for Environment-Behaviour Studies (cE-Bs), Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.
doi:10.1016/j.sbspro.2012.12.273

grassy surfaces had a potential role for the cooling effect. In a recent study on the heat island phenomenon in Singapore city, Wong and Yu (Wong & Yu, 2005) found the cooling effects of the city's green areas were reflected not only in vegetated areas but also in the surrounding areas, particularly at the leeward side of the green area. Johansson and Emmanuel's study in Sri Lanka also confirmed that the land cover of the city centre which had more of hard cover brought more thermal discomfort when compared with rural areas (Johansson & Emmanuel, 2006).

As green space should provide a healthy and comfortable environment for its users, it is reasonable to consider how people adapt to that environment. For instance, one of the most important ergonomic factor is thermal comfort, which is defined by, "the state of mind that expresses satisfaction with the surrounding environment" (ANSI/ASHRAE Standard 55, 2004). When designing an urban park, it is crucial to design it to be thermally comfortable for the users' satisfaction. Adaptive thermal behaviours can be patterned by the user's behaviour towards thermal comfort; such as changing posture and clothes, using air-conditioner or avoiding the heat sources. When thermal stress or dissatisfaction still occurred despite attempted adaptations, the situation could become harmful to the users. Hence, the study of outdoor thermal comfort becomes crucial.

When designing sustainable green space, addressing outdoor thermal comfort and heat stress have become more a prevalent focus. Therefore, the physiological and psychological impact should have been taken into account when designing green spaces. Previous studies described thermal comfort as a fundamental parameter, as well as how heat stress/thermal discomfort affects these outdoor activities (Knez et al., 2009; Nikolopoulou & Steemers, 2003; Vanos et al., 2010). These studies explained the consequences, implication and outcomes of how heat stress affected human life. Givoni et al.(2003)mentioned while staying outdoors, people should have various unlimited condition like the sun and shade, changes in wind speed, and so on. Moreover, some studies stated the need of shades as an important element for outdoor spaces (Akbari et al., 2001; Hwang et al., 2010). Comparisons between demography were also studied; between the age group(Kenny et al., 2010), gender (Gagnon et al., 2009), clothing type (Davis et al., 2011; Gavin, 2003; Havenith, 1999) and area of living in thermal comfort studies worldwide (Thorsson et al., 2007). However, studies on heat stress in tropical countries are still inadequate (Djongyang et al., 2010).

Thermal comfort becomes an overall motivation as a person's well-being could be related to climate and weather. Since park users would always look at weather conditions when doing outdoor activities, designers should apply the ergonomics factors as influential aspect for outdoor spatial design. In addition, urban parks offer the public some release from the pressures of urban environments and everyday living. Microclimatic condition wise, there may be limitations to the thermal conditions during daytime that may affect prolonged usage of the outdoor parks. An assessment of human responses to the outdoor environment and the individual user's experience is necessary to determine the people's understanding of the condition. The setting of an outdoor park pointedly influences how that space is perceived and used.

This paper suggests two research question that should be proven from the analysis; the first: Do personal factors affect the comfortable level? And secondly: How do the respondents adapt to the microclimate condition? This study aims to clarify the perceptive and adaptive mechanisms involved in outdoor thermal comfort and weather assessment. The objective of this study was to identify the people's adaptation towards the hot and humid outdoor condition.

1.1. Outdoor thermal comfort

Thermal comfort can be defined as a condition in which individuals prefer neither warmer nor cooler temperatures i.e., the preferred temperature. While neutrality temperature is the temperature at which people feel comfortable, preferred temperature is the temperature people want (Staiger et al., 2012).Thermal comfort standards, such as ASHRAE/ANSI 55, suggested seven points of thermal comfort scale: -3, -2, -1, 0, 1, 2 and 3, where -3 and 3 are on the opposite ends and 0 for comfort (Table 1). The concept of thermal comfort is closely related to thermal stress. Many researchers have explored ways to predict the thermal sensation of people in their environment based on the personal, environmental and physiological variables that influence thermal comfort. As a result, several mathematical models that simulate occupants' thermal response to their environment have been developed. Most thermal comfort prediction models use a seven or nine point thermal sensation scale, as shown in Table 1.

Table 1. The comfort/sensation scale

ASHRAE scale		Bedford scale		Seven point		Nine point	
Hot	-3	Much too warm	-3	Very cold	1	Very cold	-4
Warm	-2	Too warm	-2	Quite cold	2	Cold	-3
Slightly warm	-1	Comfortably warm	-1	Cold	3	Cool	-2
Neutral	0	Comfortable	0	Comfort	4	Slightly cool	-1
Slightly cool	1	Comfortably cool	1	Hot	5	Neutral	0
Cool	2	Too cool	2	Quite hot	6	Slightly warm	1
Cold	3	Much too cool	3	Very hot	7	Warm	2
						Hot	3
						Very hot	4

The general energy balance equation is as follows (ANSI/ASHRAE Standard 55, 2004);

$$M - W = C + R + E + C_{res} + E_{res} + S \qquad (1)$$

where, M is metabolic rate (W/m^2), W is mechanical power (W/m^2), C is convective heat loss from skin (W/m^2), R is radiation heat loss from skin (W/m^2), E is evaporative heat loss from skin (W/m^2), E_{res} is evaporative heat loss from respiration (W/m^2), C_{res} is convective heat loss from respiration (W/m^2) and S is the rate of body heat storage (W/m^2).Nicol (2004)suggested that most indoor thermal comfort standards (which were developed in Europe) were not satisfactorily defined if applied in a tropical climate. For instance, the prediction of comfort using ISO7730 in hot climates declared limitations of the applicability of the PMV, which are shown in Table 2.Tropical climates usually recorded more than 30 °C of air temperatures (T_a) during the day and air velocities in excess of 1 m/s which can be difficult to address when designing outdoor green space in actual conditions. Some studies also indicated that with the presence of wind, even when the T_a wasmore than 30 °C, thermal comfort is perceived.

Table 2. Limitations to the range of conditions over which PMV applies [10]

Variable	Symbol	Units	Lower limit	Upper limit
Metabolic rate	M	W/m^2 (met)	46 (0.8)	232 (4)
Clothing insulation	I_{cl}	◦C/W (clo)	0 (0)	0.310 (2)
Air temperature	t_a	◦C	10	30
Radiant temperature	t_r	◦C	10	40
Relative air velocity	v_{ar}	m/s	0	1.0
Water vapour pressure	p_a	Pa	0	2700
Predicted mean vote	PMV		-2	+2

1.2. Psychological and physiological adaptation

The adaptation to thermal comfort included physical and physiological process (Huizenga et al., 2001; Sanesi et al., 2006). Therefore, the physiological and psychological impact needed to be taken into account when designing green spaces. Previous studies described thermal comfort as a crucial parameter and thermal discomfort affected these outdoor activities (Hartig, 2008; Nikolopoulou et al., 2001; Stathopoulos et al. 2004). These studies explained the consequences, implication and outcomes of how heat stress affected human life. Moreover, some studies confirmed the importance of shaded areas when designing outdoor spaces (Hwang et al., 2010; Makaremi et al., 2012). Previous studies also confirmed that people adapted to varying outdoor conditions through behavioural and postural changes, acclimatization and their perception of the outdoor conditions (de Dear & Brager, 2001; de Dear & Brager, 1998). Psychological adaptation towards environmental ergonomic is necessary to encourage better usage of outdoor space. Human responses to the outdoor environment and actual thermal sensation experienced by individuals are vital to determine the people’s level of understanding of the condition.

2. Materials and Method

2.1. Study area

The study area for the microclimate measurement was at the Shah Alam Lake Garden, Malaysia, positioned at 3° 5’ 00” N, 101° 32′ 00″ E,which is the main public park for Shah Alam residents. There were an abundance of Samanea saman (rain tree) and Pterocarpus indicus (Angsana) that shaded the area and the ground was covered by graminoid like Axonopus compresus(common grass) (Figure 1). There was also a playground within the perimeter with sitting and resting places for picnicking and leisure activities.

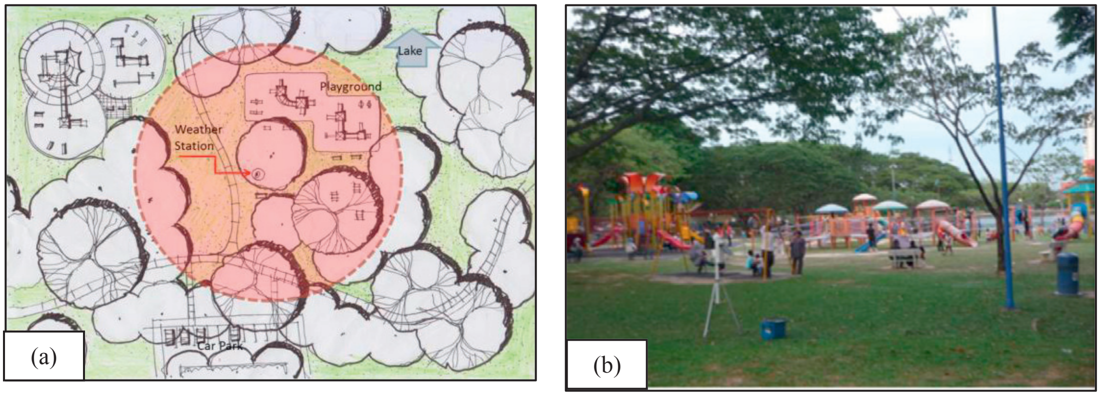

Fig. 1. (a) Sketches plan of the study area (not to scale); (b) View of the studied area showing position of portable weather station

The main attraction of the 43ha Shah Alam Lake Garden is the beautifully landscaped green areas. There are also cafes, playgrounds, jogging tracks, lakeside promenades, and gazebos, resting area, water features and massive lakes. The study area was accessible to pedestrians and access limited to bicycles. The section of the study area is shown in Figure 2.

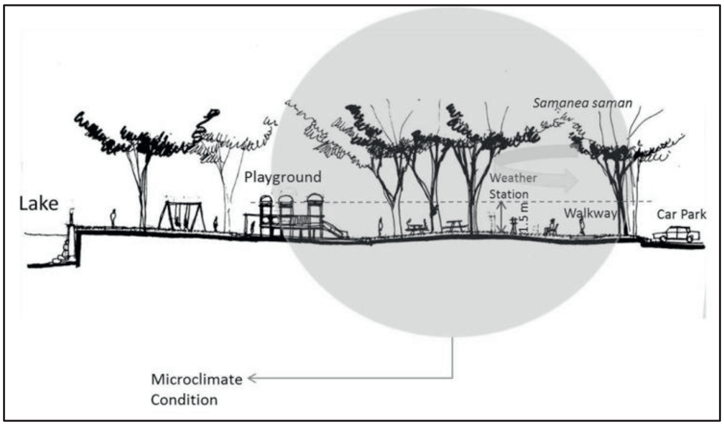

Fig. 2. Section of the microclimate study site (not to scale)

2.2. Microclimate condition

The climate of Shah Alam (Subang Jaya station) is classified as hot and humid. The local climate is equatorial and characterised by the annual southwest (April to October) and northeast (October to February) monsoons. The relative humidity was also high which was between 50 and 99%. The trends of the climate condition in Shah Alam are shown in Figure 3.

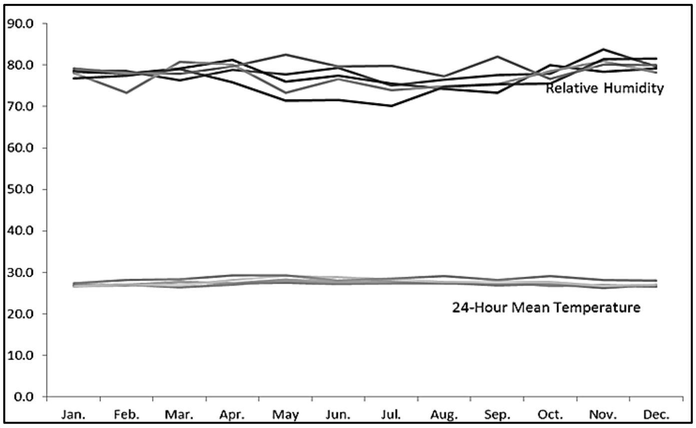

Fig. 3. Meteorological Trends in Shah Alam in 2006-2010
(Source: Malaysian Meteorological Department)

The measured microclimate parameters were Air Temperature (Ta), Relative Humidity (RH), Wind Velocity (v), Solar Radiation (I), Apparent Temperature (AT), Mean Radiant Temperature (T_{mrt}) and calculated PET as shown in Table 3. A portable weather station positioned 1.5 m from ground was used for data collection (Figure 1b). The measurements were taken on days 70, 99, 134, and 161 of the year respectively. The measurement days were selected by referring to the weather forecast published by the Malaysian Meteorological Department website. The selected days excluded rainy days. The data was collected between 0700 and 1900 h each day at 10-min intervals with the total N is 292.

Table 3. Measured microclimate parameter

Parameters	Min	Max	Mean ± Std. Error		Std. Dev.
T_a(°C)	24.4	32.2	28.5	± 0.1	1.8
RH (%)	52.0	96.0	70.8	± 0.6	9.9
v (ms^{-1})	0.0	3.1	1.3	±0.0	0.8
$T_{apparent}$ (°C)	27.2	36.7	32.3	±1.3	2.2
T_{mrt}(°C)*	24.5	50.5	33.3	± 0.3	4.9

Apparent Temperature was calculated using Equation 2 (Steadman, 1984). The following formula is applied in the calculation as follows:

$AT= T_a+0.33 \times e - 0.70 \times v - 4.00$ (2)

where T_a is air temperature (°C), e is water vapour pressure or humidity (hPa), and v is wind speed (m s^{-1}). The vapour pressure, e is calculated from air temperature and relative humidity using the Equation 3(Steadman, 1984).

$e = RH/100 \times 6.105 \times EXP(17.27 \times T_a/(237.7+T_a))$ (3)

where RH is Relative Humidity (%).

2.3. Interview sheets and observation

The interviews were conducted simultaneously with the microclimatic measurements. The questions consisted of demography (age, gender, activities, and origins) clothing, the reason(s) for being at the park and time spent outdoors. The respondents were asked to express their feeling regarding wind, air temperature, humidity, brightness, and the overall condition suitability with the microclimate. Each interview took an average of 5 minutes to complete. On average, 73 interviews were conducted daily during the measurement. The park physical features and users' behavioural pattern were observed.

3. Results and Findings

3.1. Thermal comfort level

The Physiological Equivalent Temperature (PET) was estimated using the RayMan model (Matzarakis et al., 2007)which calculated the radiation fluxes within urban structures based on certain parameters, including T_a, Wind Velocity (v), Solar Radiation (I) and surrounding surfaces. The results of calculated PET for the measured days using Rayman application are shown in Figure 4. The results showed that 11.6% of PET were comfortable, 66.4% slightly warm, 19.9% warm and 2.1% hot. The range of PET was between 20.8 and 39.70°C which belonged to the warm zone.

Another way to clarify the thermal comfort level is by employing apparent temperature (AT). AT (calculated of T_a and h) showed better understanding of the value of how Malaysians adapt to the hot and humid outdoor condition. Figure 5 shows the apparent temperature captured in this study. The range of AT was between 27.2 and 36.7°C. The AT comfortable range was between 20 and 29°C. Therefore, this study showed that the condition during measurement days was in the "some discomfort" range which when occured in hot weather, the body produced sweat, which cooled the body as it evaporated and created some discomfort condition.

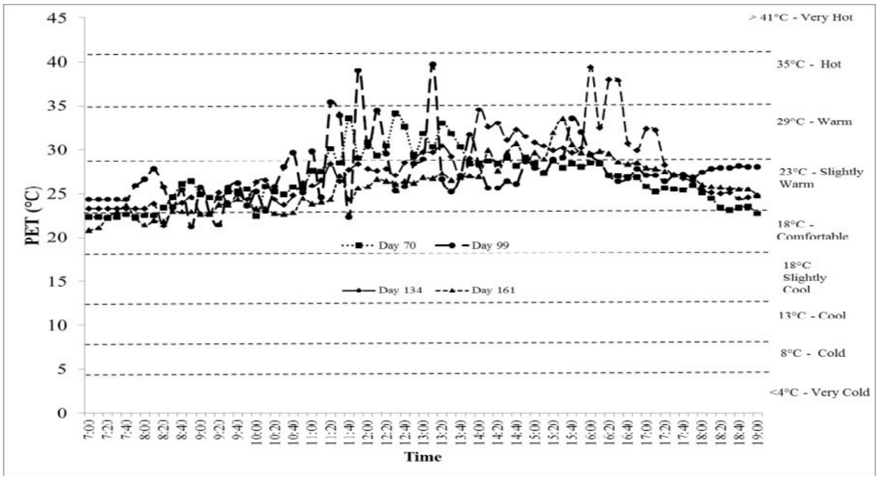

Fig. 4. Calculated physiological equivalent temperature (PET)

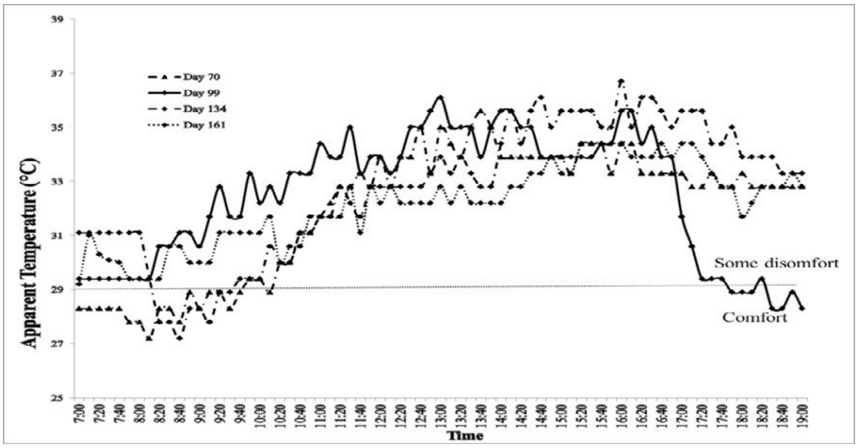

Fig. 5. Apparent Temperature (AT)

3.2. Physiological adaptation

The analysis between Physiological Equivalent Temperature (PET) level, age and gender provided the hypothetical argument. Table 4 shows the classification of Age Group and Gender. The age bands were divided into five categories using Target Group Index; Under 15, 16-24, 25-44, 45-64 and Above 65.The analysis found that there was a significant finding on gender and age with their comfort level as shown in Table 5.

Table 4. Descriptive statistics of age group and gender

Age Group	Gender	Mean	Std. Deviation	N
Under 15	Male	5.50	.707	2
	Female	6.50	.707	2
	Total	6.00	.816	4
16-24	Male	5.92	.494	13
	Female	6.14	.640	22
	Total	6.06	.591	35
25-44	Male	6.24	.557	80
	Female	6.13	.620	128
	Total	6.17	.597	208
45-64	Male	5.79	.787	19
	Female	6.04	.562	23
	Total	5.93	.677	42
Above 65	Male	5.00	.	1
	Female	7.00	.000	2
	Total	6.33	1.155	3
Total	Male	6.10	.627	115
	Female	6.14	.616	177
	Total	6.12	.619	292

Table 5. Test between age group and gender on Physiological Equivalent Temperature (PET)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.704[a]	9	.856	2.324	.015
Intercept	1325.980	1	1325.980	3600.358	.000
Age Group	2.921	4	.730	1.983	.097
Gender	4.128	1	4.128	11.210	.001
Age Group* Gender	5.214	4	1.303	3.539	.008
Error	103.858	282	.368		
Total	11060.000	292			
Corrected Total	111.562	291			

a. R Squared = .069 (Adjusted R Squared = .039)

The covariate, Age Group, was not significantly related to the Physiological Equivalent Temperature (PET) F (4, 282) =1.983, p < .05, r = .1. However, the Gender showed significant effect on PET level after controlling other factors, F (1, 282) = 11.210, p < .05, r = .01. In summary, two factors, Age and Gender has been selected to correlate with the physiological condition. The Age Group did not significantly influence the comfortable level, yet, the Gender showed significant outcomes. Figure 6 shows how male and female interrelate with the PET level.

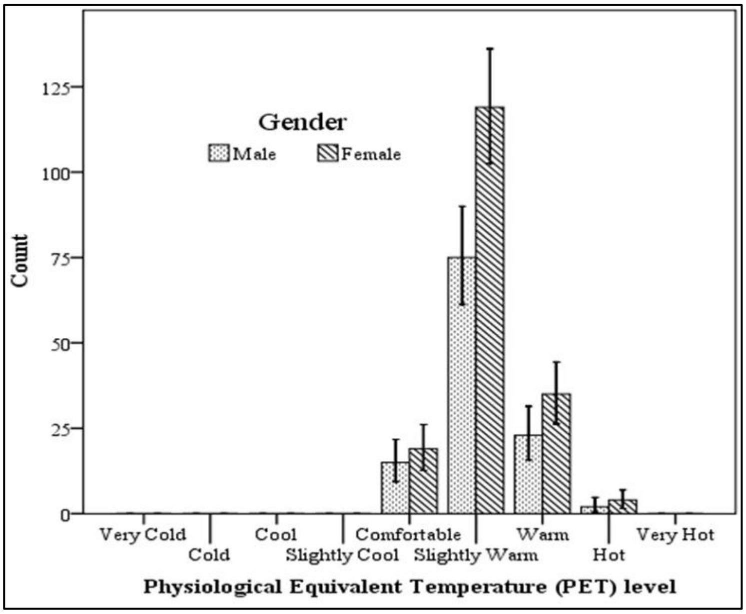

Fig. 6. PET level by male and female

3.3. Psychological adaptation

Outdoor thermal comfort for the tropical climate is a positive attribute as it ensures better tolerance to outdoor conditions, which in turn, encourages better usage of outdoor recreational areas. This study was conducted to verify that Malaysians psychological adapt to a higher range of outdoor thermal condition than comfortable level of Physiological Equivalent Temperature (PET) than temperate climate (Mayer & Höppe, 1987).

3.3.1 Thermal Sensation Vote (TSV) and Physiological Equivalent Temperature (PET)

The respondents (N=292) were requested to express their thermal sensation, according to a 9-point scale. This was then compared with that estimated by the PET index (Figure 7) (as compared with the study done in temperate climate (Matzarakis & Amelung, 2008). The majority of the respondents expressed their thermal sensation as comfortable.

The variety of the respondents answers were cold (0.7%), cool (4.1%), slightly cool (8.2%), comfortable (69.5%), slightly warm (12.7%), warm (3.1%) and hot (1.7%) as shown in Figure 6. Then, the TSV was compared to the PET range.

The results proved that the respondents adapted to a higher range of thermal conditions (21.1 - 39.4°C of PET) compared with the comfortable range of PET (18 – 23 °C) in Europe. Almost 70% of the subjects confirmed that they psychologically perceived and adapted better to the outdoor conditions.

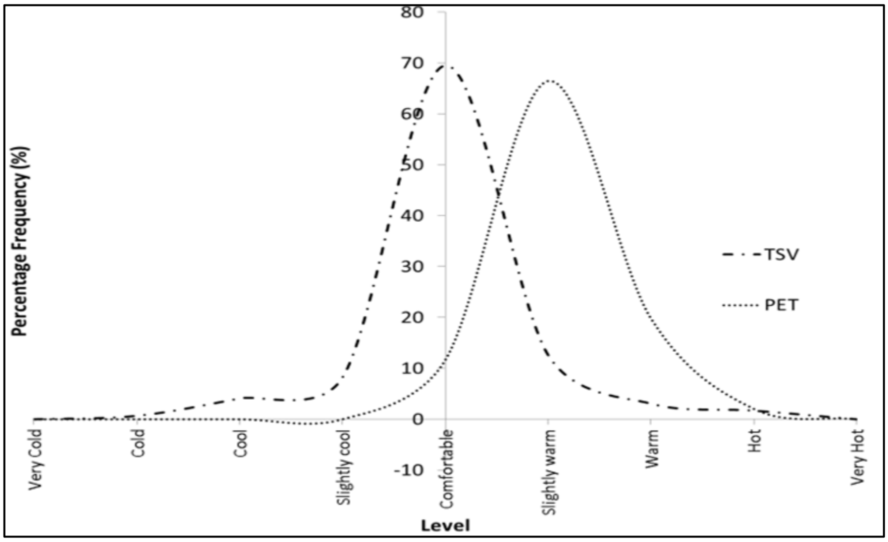

Fig. 7. Percentage frequency (%) on Thermal Sensation Vote (TSV) and Physiological Equivalent Temperature (PET)

3.3.2 Meteorological indices and respondents' vote comparison

The respondents were asked about their perception towards the actual microclimate conditions; wind, heat and humidity. The weather station data was then classified into standard rating. Then, the counts of the level were compared. Figures 7, 8 and 9show the frequency percentage on the perception of respondents and the actual measured data classified by specified indices.Figure 7 shows the comparisons between the wind speed level and the perception of the respondents towards wind flow. The x axis of this graph shows the classified level of wind speed (Bedford scale) and respondents perception on wind while frequency percentages (%) appear on the y axis. The wind speed ($m\ s^{-1}$) level is classified into five categories; <0.3 is Calm, 0.3-1.5 is Light Air, 1.5-8.0 is Breeze, 8.0-10.8 is Strong Breeze and >10.8 is Windy. It may be seen clearly that the wind condition is mostly fell into "light air" yet; the respondents sensed it as the "breeze". The measured wind speed showed that there were light winds dominating the area, yet, the respondents felt more breeze than light wind.

Figure 8 shows the classified level of Apparent Temperature (AT) and perception on heat sensation in frequency percentage (%). The Apparent Temperature (AT) (°C) are classified based on Environment Canada rating level in five categories; <14 Cold, 14-20 is Cool, 20-29 is Neutral, 29-39 is Warm and >39 is Hot. The findings showed that the respondents answered in symmetrically distributed, yet, the measured AT mostly fell into "Warm" category. The measured $T_{apparent}$ showed that the actual condition of the study area was warm and should create some discomfort. However most of the respondents rated the $T_{apparent}$as neutral. Figure 9 shows the classified level of Relative Humidity (RH) and perception on the humidity in frequency percentage (%). The RH (%) are classified evenly into three categories; <30 is Dry,30-60 is Neutral, and >60 is Damp. The findings shows that the respondents answer in symmetrical distributed, yet, the measured RH is mostly fall into "Damp". Moreover, the measured RH fell into "damp" level but the respondents felt neutral. In conclusion, the results showed significant findings that agreed with the theory of adaptive comfort where people living in the tropical climate adapted to higher temperature, more humid and less breezy conditions.

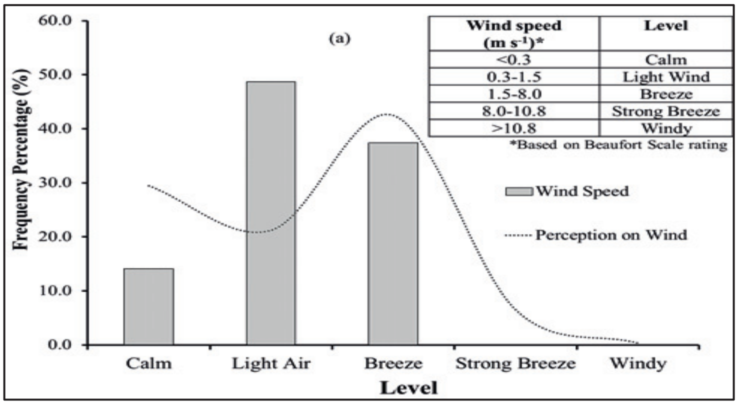

Fig. 7. Frequency percentage (%) of respondents' perception and microclimate measured data on wind speed

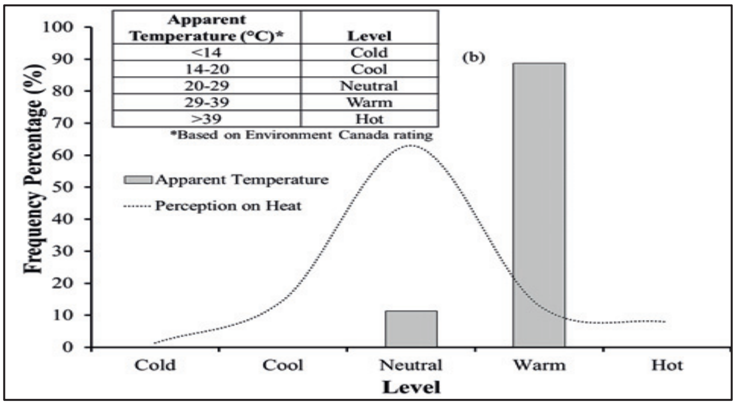

Fig. 8. Frequency percentage (%) of respondents perception and microclimate measured data on Apparent Temperature (AT)

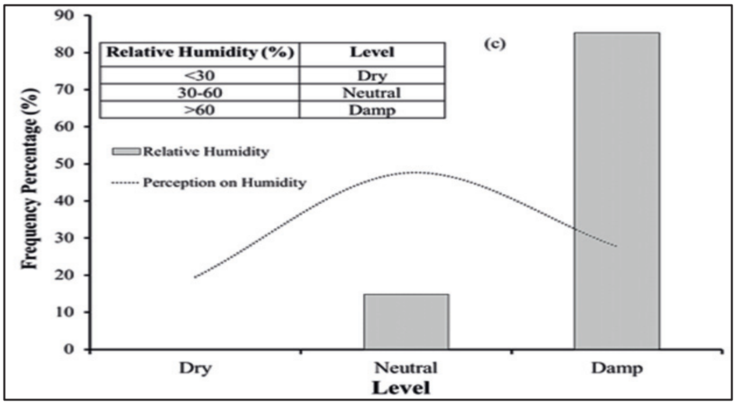

Fig. 9. Frequency percentage (%) of respondents perception and microclimate measured data on Relative Humidity (RH)

4. Summary

This study explored the people's perception on the microclimate condition of a Malaysian urban recreational area. The results confirmed the existence of adaptive thermal comfort amongst the respondents whereby they perceived better microclimatic conditions than what was measured. It showed how Malaysian understood and perceived about microclimate. There is still room for further research with wider sampling to determine the adaptations of subjects to the microclimate.

The findings on the significant influences of microclimate parameters (air temperature, wind velocity, Apparent Temperature (AT), Physiological Equivalent Temperature (PET)) and personal factors (demographic) on the participants' perceptual and emotional estimations of outdoor urban places were discussed. This study confirmed that the subjects adapted to the "warm" rather than the "comfortable" range of Physiological Equivalent Temperature (PET), which contradicted with their perception that responded positively to much warmer physical environment. Moreover, the Apparent Temperature (AT) showed how the Malaysian subjects adapted to the "discomfort" level of PET, yet still felt "comfortable". Furthermore, the respondents' perceptions on the microclimate condition varied according to factors such as age, gender, race, and the respondents' activities.

The objective of this study was to examine the thermal comfort levels of Malaysians in a recreational park which had the condition of hot and humid, and even shaded area. The hypothesis on this research proved that personal factors did not affect the comfortable level, and there are must be another factors impacting the preferences. And for the second hypothesis, the respondents adapted into the microclimate condition which is hot and humid.

The findings showed that the Malaysian subject were physiologically and psychologically adapted to the shaded microclimate condition based on their experience and perception. The significance of the findings showed the importance of sustainable urban parks for continued use by future communities. The findings may contribute to the theory and design of sustainable urban parks for present and future communities.

Acknowledgements

This research has been funded by the Ministry of Higher Education under the Fundamental Research Grant Scheme (FRGS) file no: 600-RMI/ST/FRGS 5/3/Fst (104/2012) and UiTM's Excellence Fund file no: 600-RMI/ST/DANA 5/3/Dst (75/2011).

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