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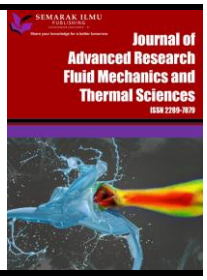

A Comparison in Perception of Local and Foreign Residents to Thermal Comfort in Naturally Conditioned Residential Buildings

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ABSTRACT

Thermal comfort is the individual satisfaction with the surrounding thermal environment. It is mainly affected by environmental factors (i.e., air temperature, relative humidity, air movement, and mean radiant temperature) and individual factors (i.e., activity and clothing). However, other factors such as acclimatization, experiences and expectations, food and drink, body shape and subcutaneous fat, age and gender, and state of health might play a significant role in the individual sensation and satisfaction of the thermal environment. This study investigates the possible differences in thermal perception between local and foreign residents, which might occur due to the influence of the individual and contributing factors that are linked to their thermal, cultural, and behavioural backgrounds. High-rise residential buildings that accommodate local and foreign residents were selected, and a questionnaire survey was distributed to assess their thermal comfort perception. The results showed differences between local and foreign residents in thermal comfort perception. The foreign residents were more satisfied and comfortable with the thermal environment compared to the local residents. However, this difference was found to be statistically insignificant; therefore, it might be linked to factors linked to the current study, including acclimatization, expectation, clothing insulation and activity levels. Therefore, a further large-scale investigation might be required with more analysis on the role and influence of the contributing factors on the thermal sensation of different gropes.

1. Introduction

A standout amongst the most important elements that influence our life, productivity, and well-being is our surrounding thermal environment. Being comfortable in this environment positively enhances our life and performance [1]. Therefore, building design should provide more thermal stability to enhance thermal comfort levels [2]. To be thermally comfortable is to be satisfied with the surrounding thermal environment [3-5]. This satisfaction is derived by controlling some factors

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in the environment (i.e., air temperature, relative humidity, air movement, and mean radiant temperature) as well as in the individuals (i.e., activity and clothing) [3,6-8]. These six factors are the main factors in Fanger's classic equation for thermal comfort, which determines the human body heat balance based on a study-state condition [9,10]. However, many other factors related to the cultural, behavioural and thermal backgrounds of individuals might influence their thermal comfort perception in the real world [11]. These factors can be grouped as the contributing factors, which include acclimatization, experiences and expectations, food and drink, body shape and subcutaneous fat, age and gender, and state of health [12].

Lin and Deng [13] mentioned that comfort is a state of mind rather than a state of condition. Thus, it is influenced by many factors, including physical, physiological, psychological, and other factors. Therefore, it is quite challenging to satisfy everyone in the same thermal environment [14-16]. The influence of the environmental factors in a place with people from different thermal backgrounds (i.e., various countries with diverse climatic conditions) will remain the same. In contrast, the individual and contributing factors can have different influences on individuals who come from different places due to various thermal, behavioural, and cultural backgrounds. That is why these individuals have different opinions on thermal comfort [17]. Luo *et al.,* [18] mentioned that the comfort perception of individuals is closely linked to their thermal history and that a long-term thermal experience might shift their thermal expectations. In addition, individuals' satisfaction is a result of the balance between the physical environment and their comfort expectations, which are linked to their recent experiences. Furthermore, they found that a long-term thermally comfortable experience raises the thermal expectation, while the experience of a non-neutral thermal environment can activate the adaptation process. Therefore, thermal comfort and satisfaction are linked with the thermal, social and cultural backgrounds and are highly negotiable [18-20].

As mentioned above, individuals, especially those from different backgrounds, have different sensations of thermal comfort due to various factors [17]. Some of these factors are discussed below:

1.1 Clothing and Metabolic Activity

Rijal *et al.,* [21] found higher differences in comfort temperature up to 4.9-13.8 K according to the seasons, resulting from the variation in the seasonal clothing insulation and wind velocity and subjects' adaptation. Additionally, Arens *et al.,* [22] linked some of the variations in the temperature's acceptable range of the occupants to their clothing. They found that with clothing change from 0.5 to 1 clo, the change in air temperature corresponds to 3 k. However, Indraganti *et al.,* [23] stated that clothing was found to be restricted by the use of fixed costumes (e.g., office dress) or by socio-cultural practices, especially among women. On the other hand, Indraganti [24] noticed that most subjects were slowing down their activity during the summer afternoon, while some subjects delayed heavy household activities to morning or evening to avoid discomfort. Furthermore, around 20% of the subjects preferred to lie down during the midday. He also indicated that clothing and metabolic activity were often restricted by temporal and cultural limitations.

1.2 Acclimatization

Acclimatization is "*an unconscious response mediated by the autonomic nervous system, which directly reset our physiological thermoregulation set points*" [25]. Physiological short-term adjustment to diverse conditions is achieved in 20 - 30 minutes, while long-term adjustments for the endocrine may last for more than six months, which forms the acclimatization process [12].

Therefore, people may prefer warmer than normal conditions in hot climates and cooler than normal conditions in cold climates. This influence may be apparent in uncomfortable warm or cold environments. People who used to work and live in warm climates can easily accept hot environments than people from colder climates [26]. Mishra and Ramgopal [27] mentioned that the neutral temperature of the occupants during wintertime with active heating was reduced by 1.1 ℃ compared to the ten years earlier neutral temperature and was attributed to the acclimatization of the occupants [28].

1.3 Experiences and Expectations

Psychological adaptation involves the effects of cognitive and cultural variables and describes to which extent the experiences and expectations modify thermal perceptions [25]. The optimal adaptation levels result from past exposure and perform as benchmarks for environmental assessments. In an environment with a temperature less than perfect, the person's reaction will depend essentially on his expectation, personality as well as what he is doing during that time. Subjects who experience a cool environment in summer on the previous day will usually indicate warmer thermal sensations [29]. It was mentioned that the influence of being in an artificial climate in the office, home, and vehicles is shown in the subjects' choices of comfort votes [27]. Furthermore, Rupp *et al.,* [11] in their work reviewed a few thermal comfort studies that account for the past thermal experience. They mentioned that a cooler thermal sensation was obtained by subjects who were exposed to higher temperatures. In contrast, a warm thermal sensation was obtained by subjects who were exposed to an air-conditioned environment. In addition, being in a non-air-conditioned environment just before moving to a naturally conditioned environment produces a no-change preference, while being in an air-conditioned environment produces a cooler preference. In fact, people in naturally ventilated environments have a wider acceptance range compared to those in air-conditioned environments [30].

1.4 Food and Drink

Food and drink can influence the individual's metabolic rate (i.e., activity level). The intake of food causes a certain increase in internal heat production, which may have an impact on thermal comfort. Thus, after a heavy protein-rich meal, the preferred ambient temperature might be decreased by up to 1K for some hours [31].

1.5 Body Shape and Subcutaneous Fat

The body shape and subcutaneous fat also have an influence on the thermal sensation of the individuals. Production of the heat is equivalent to the mass of the body, whereas dissipation of the heat depends on the body's total surface [12]. Differences in body shape influence the body heat balance, and their thermoregulation and thermal perception will differ [27]. The ratio of body surface to volume for a thin person may be greater than for a rounded-body person; thus, it can dissipate more heat to the environment. Therefore, the rounded-body person would prefer a lesser temperature, partly due to the lower ratio of the body surface to the volume, but further because subcutaneous fat is a good insulator [11,12].

1.6 Age and Gender

Age and gender also influence thermal preferences. Older people, for example, tend to have a narrower thermal comfort zone [11,32]. Their metabolism decreases slightly with age but is also combined with a lower evaporative loss [11]. In fact, older people usually prefer higher temperatures than young adults, which may be attributed to their lower activity levels [27]. On the other hand, females have slightly lower metabolic rates than males [11]. Yet, their skin temperature and evaporative loss are slightly lower than those of males, which balances the lower metabolic rates. Nevertheless, they usually prefer higher temperatures (i.e., 1 K) compared to males, which may be explained by their lighter clothing [26]. Schellen *et al.,* [33] found that females were more uncomfortable and dissatisfied compared to males within the same thermal conditions, and to satisfy the females, the operative temperature is required to be increased by 1.2 K. Furthermore, females have a higher sensitivity to cold environments and are more likely to be dissatisfied, while males prefer slightly cold environments [11,32]. Similarly, Maykot *et al.,* [34] found the comfort temperature for females was higher than for males in mixed mode and fully air-conditioned office buildings. They also concluded in their other work that the thermal comfort sensation of individuals is affected by gender [35].

Based on the discussion above, the present study was conducted to investigate the perception of local and foreign residents regarding thermal comfort and to which extent this perception might differ between the two gropes due to the individual and contributing factors that are linked to their thermal, cultural, and behavioural backgrounds. High-rise residential buildings that accommodate local and foreign residents were selected and questionnaire surveys were distributed to the residents in their homes to investigate their perception of thermal comfort and to collect all the required data.

2. Methodology

According to ASHRAE [4], thermal comfort sensation is assessed by subjective evaluation. Therefore, a quantitative approach was carried out using questionnaire surveys on thermal comfort. Many researchers used this method to examine subjective perception and behaviour [11,35-38]. The present work is part of a study investigating the residents' perception of thermal comfort and their adaptive behaviour in high-rise residential buildings. The main target of the current work is to determine to which level the residents from different countries might experience different thermal comfort perceptions due to the influence of the individual and contributing factors that are linked to their thermal, cultural, and behavioural backgrounds.

A high-rise residential condominium consisting of four buildings with a total of 988 flats was selected to distribute the questionnaires in this research. These buildings are occupied by local and foreign residents due to their locations close to one of the Malaysian universities. Assuming one participant in each flat, 150 questionnaires were distributed based on Cochran's sample size equation and a 70% return rate [39,40]. However, the collected questionnaires were less than the required sample size; therefore, another 50 questionnaires were distributed. The researchers' efforts were made to get participation from a roughly equal proportion of local and foreign residents, male and female, with a range of ages, and to involve participation from different floor levels and daily periods. All questionnaires were distributed only to the residents in their homes from 9.00 am to 9.00 pm to ensure good cooperation from residents and to ensure that they answered the questionnaires in their homes. In addition, the questionnaires were distributed during February and March, representing the beginning of the warmer months that might extend to June, according to the Malaysian meteorological department [40].

Beyond the general background information of the residents (i.e., gender, age, weight, etc.), foreign residents were asked to indicate the climate of their countries by selecting hot, moderate, or cold. Moderate climate reflects that the respondent is not from an extremely hot or cold climate but might experience both hot summer and cold winter. The reason for selecting these three types was to identify whether or not the foreign respondents were from a hot climate similar to the climatic condition of the current research. Additionally, they were asked about the extent of their living in Malaysia, indicating their acclimatization to the local climatic conditions. On the other hand, local residents were asked to indicate their ethnicity by selecting Malay, Chinese or Indian. Many researchers found that thermal comfort perception differs between the three groups [40-42].

Moreover, all residents were asked to specify their clothing level (i.e., very light, light, medium or heavy) and their activity for the last hour before filling in the questionnaire (i.e., sleeping/lying, cooking, house cleaning, seating/reading/writing and others). Besides, they were asked to indicate their use of air-conditioners (AC) outside their homes, mainly at work and in their cars, as it might influence the body and mind's state to seek cooler conditions once they return home, which forms their expectation levels. On the other hand, residents' votes for the thermal environment were collected using seven-point scales, which include the thermal sensation (TS) scale (i.e., ASHRAE scale) and comfort perception (TC) scale (i.e., Bedford scale) [4,11,35,43,44]. In addition, two other scales were used, including votes of preference and direct votes of acceptability (Figure 1).

Finally, to ensure that the respondents were in a naturally conditioned space, the residents were asked to indicate whether they were using the AC at the moment of answering the questionnaire. Only those who answered "No" were considered in this study.

+3	Hot	+3	Much too warm			
+2	Warm	+2	Too warm			
+1	Slightly Warm	+1	Comfortable warm	+1	Warmer	Acceptable
0	Neutral	0	Comfortable	0	No change	
-1	Slightly Cool	-1	Comfortable Cool	-1	Cooler	Not Acceptable
-2	Cool	-2	Too Cool			
-3	Cold	-3	Much too cool			
ASHRAE scale		Bedford scale		Preference		Acceptability

Fig. 1. Rating scales of the survey [45]

3. Results and Discussion

Out of the 200 distributed questionnaires, 116 were collected, and only 106 were complete and valid questionnaires. Table 1 summarises the frequency and percentage of the local and foreign respondents. Researchers' efforts were made to achieve equal ratios of the two gropes. However, the result was 60% of the foreign residents to 40% of the local residents. It also shows that the percentages of male respondents to female respondents in both categories were almost 62% to 38%, respectively.

Table 1
Summary of the respondents

	Frequency	Percentage		Frequency	Percentage
Local respondents	42	40%	Male	26	62
			Female	16	38
Foreign respondents	64	60%	Male	40	62.5
			Female	24	37.5

3.1 Residents Background

Table 2 shows that nearly half of the local respondents were Chinese, followed by Malays (i.e., 38.1%) and lastly, Indians with 16.7%. Many previous studies indicated that the Chinese preferred lower temperatures compared to the others, followed by the Malays and then the Indians [40-42]. On the other hand, the figure shows that 12.5% of the foreign respondents were from hot climates, while the rest (i.e., 87.5%) were mostly from moderate climates and a small percentage from cold climates. A high percentage of the respondents come from climatic conditions different from that of the current research. Therefore, their thermal sensation might differ, and the influence of the discussed factors, such as acclimatization, can be investigated. Table 3 summarizes the respondents' age and weights. The mean age was 39.54 years and 35.42 years for the local and foreign respondents, respectively, while the mean weight was 69.10 kg and 76.44 kg, respectively. Local respondents were slightly higher in their age, while foreign respondents were higher in their weight.

Table 2
Summary of the Ethnicity of the local respondents and climate type of foreign respondents' countries

			Frequency	Percentage (%)
Local respondents	Ethnicity	Malay	16	38.1
		Chinese	19	45.2
		Indian	7	16.7
Foreign respondents	Climate	Hot	8	12.5
		Moderate	51	79.7
		Cold	5	7.8

Table 3
Summary of the respondents' age and weight

		Minimum	Maximum	Mean	Std. Deviation
Age	Local respondents	16.00	78.00	39.54	16.46
	Foreign respondents	22.00	50.00	35.42	6.62
Weight	Local respondents	50.00	95.00	69.10	11.90
	Foreign respondents	41.00	160.00	76.44	17.29

Furthermore, Figure 2 shows how long foreign respondents have been living in Malaysia, indicating their acclimatization to the Malaysian climate. As mentioned earlier, the acclimatization process might be formed after six months [12]. It is seen in the figure that the highest two percentages of the foreign respondents, which together make 78.1 % of the total respondents, have been living in Malaysia for more than two years. This indicates that they might acclimatize to the Malaysian climate and, therefore, might have more tolerance for the hot conditions.

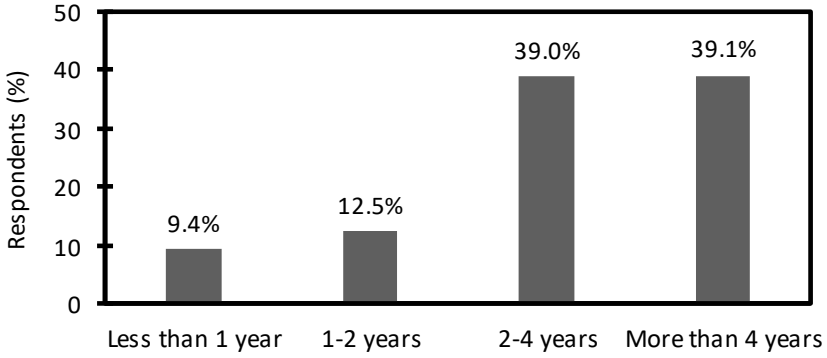

Fig. 2. Acclimatization, i.e., the extent of the foreign respondents' living in Malaysia

The expectation level of the respondents has presented in Figure 3. More than half of the respondents indicated that they always use the AC in the work, while it reached more than 80% inside the cars. However, the local residents' votes were 5.4% and 16.6% higher compared to foreign residents for using AC in their work and cars, respectively. The use of AC at work might not be controllable by individuals, yet it is fully controllable in their cars. The local respondents were more likely to use AC, especially in their cars, than the foreign respondents. This reflects their preference to stay in colder conditions, which might raise their expectation of finding similar conditions when they return home. This, in turn, will result in a feeling of being warm and uncomfortable without using AC at home. It was mentioned earlier that the influence of being in an artificial climate in the office, home and inside the vehicles prior to the experiment is shown in the subjects' choices of comfort votes [27].

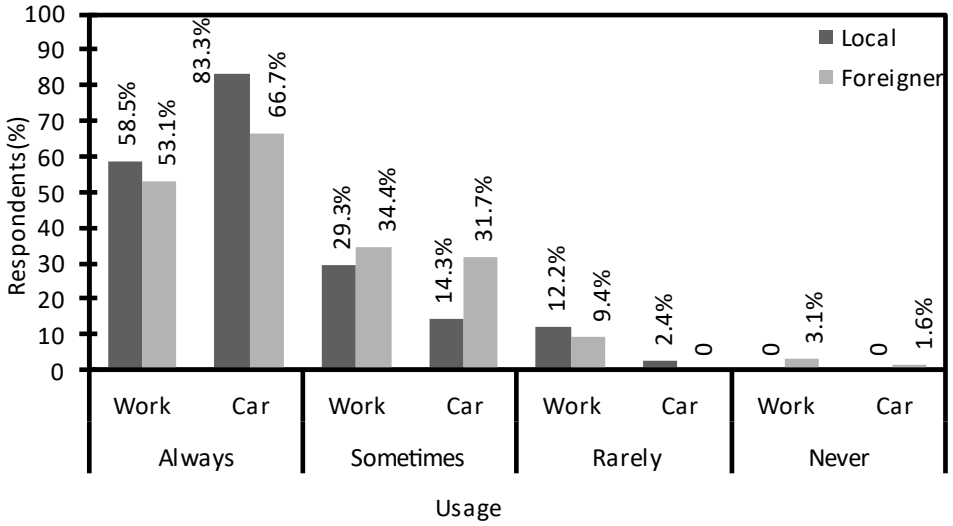

Fig. 3. (Expectation), usage of the AC outside respondents' homes

The clothing level during the survey was found to have similarities for local and foreign respondents, as shown in Figure 4. However, the percentage of the local respondents was higher in the medium clothing level. In contrast, it was higher for the foreign respondents in the light and very light clothing levels. As the clothing level increases, the body may feel warmer, resulting in the sense of being uncomfortable. Thus, local respondents with higher clothing levels might feel warmer and more uncomfortable than foreign respondents.

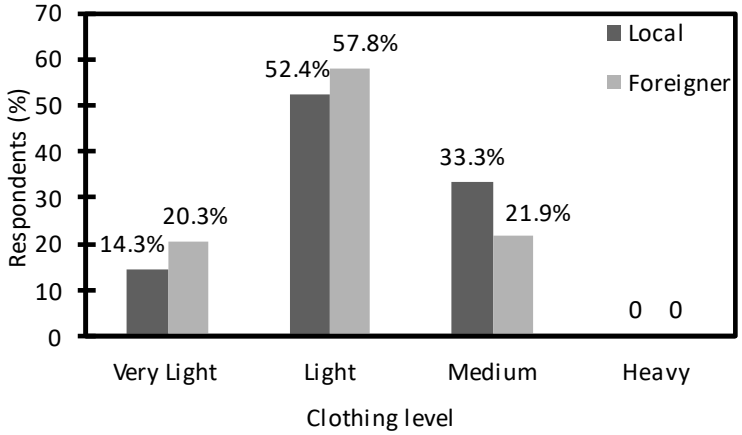

Fig. 4. Clothing level of the respondents

Figure 5 shows the activity levels of local and foreign respondents for the last hour before answering the questionnaire. Half of the foreign respondents and one-third of the local respondents were either seated, reading, or writing. However, it can be said that the percentages of the local respondents were higher in cooking, house cleaning, and other activities (i.e., performing some works as they indicated). These types of activities result in a metabolic rate of 1.6-3.4 met or higher. In contrast, percentages of the foreign respondents were higher in sleeping, lying, seated, reading, and writing activities, which resulted in a lower metabolic rate of 0.7-1 met. The high metabolic rate of the local respondents means higher energy production and heat loss, which might increase their warmth sensation.

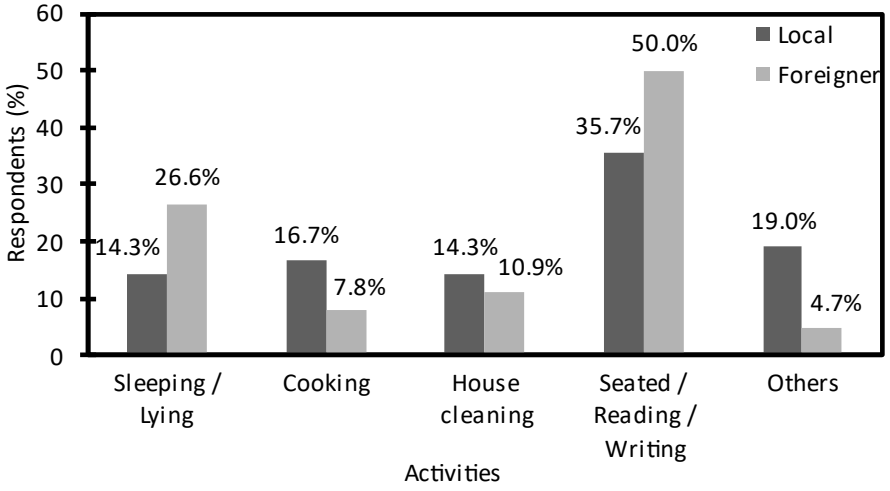

Fig. 5. Respondents' activities for the last hour before answering the questionnaire

3.2 Residents' Thermal Perception

An analysis of the thermal perception of the local and foreign respondents is carried out to find the extent of differences that might occur between the two gropes due to previously discussed individual and contributing factors. Using the TS scale (ASHRAE scale), Figure 6 shows thermal sensation votes for the local and foreign respondents. The first impression received from this figure is that the percentages of foreign respondents who feel "neutral" and "slightly cool" are higher, while local respondents who find it "slightly warm" and "warm" are higher. By using the ASHRAE standard's requirement to rate any condition as an acceptable condition, where at least 80% of occupants' votes

must be within the central three categories, it was found that 72.5% of the local respondents voted within the central three categories compared to 80.7% of the foreign respondents. Therefore, the thermal environment can be rated as an acceptable condition for the foreign respondents, while it is considered not acceptable for the local respondents.

Furthermore, similar patterns to the ASHRAE scale were found using the TC scale (Bedford scale). Figure 7 shows that the percentage of foreign respondents who found it "comfortable" is higher by 20% compared to the local respondents. In comparison, the percentage of the local respondents who found it "comfortable warm" is higher by 14% compared to the foreign respondents. It also shows that 87.5% of the local respondents voted within the central three categories compared to 91.3% of the foreign respondents. Thus, it can be said that the local respondents found the thermal environment warmer than the foreign respondents did.

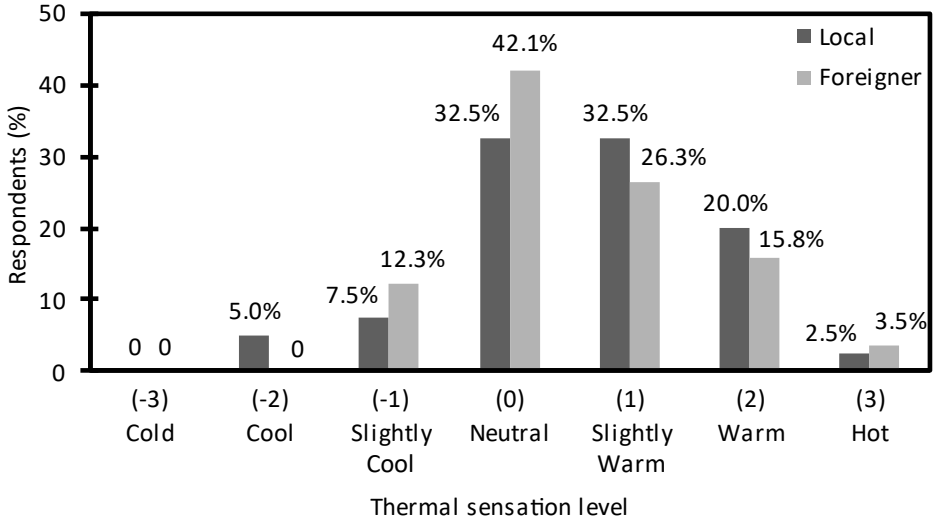

Fig. 6. Perception of the thermal environment for the Local and Foreign respondents (ASHRAE scale -TS)

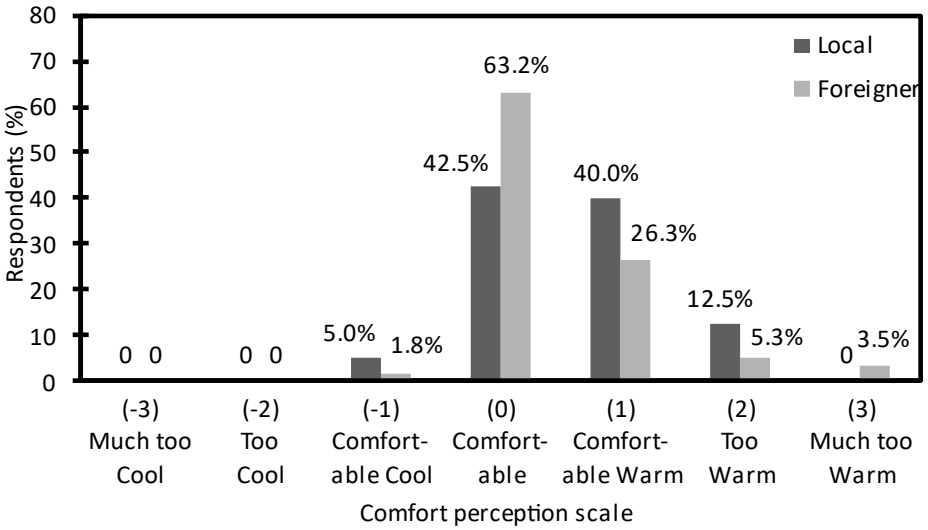

Fig. 7. Perception of thermal comfort for Local and Foreign respondents (Bedford scale -TC)

Therefore, according to ASHRAE standards, the investigated environmental condition is considered not acceptable for the local respondents, even though it is acceptable for the foreign respondents. On the other hand, considering the high tolerance of the local respondents to their hot

environment, they were found comfortable within this environmental condition according to the Bedford scale. However, the foreign respondents were more comfortable with the same environmental condition. A comparison between the local and foreign respondents regarding how they preferred to change the current environment can be seen in Figure 8(a). Although the highest percentages of both local and foreign respondents choose to be cooler, the percentage of the local respondents is higher by almost 10% than those of the foreign respondents. In contrast, the percentage of foreign respondents who voted for no change is higher by nearly 15% than the local respondents.

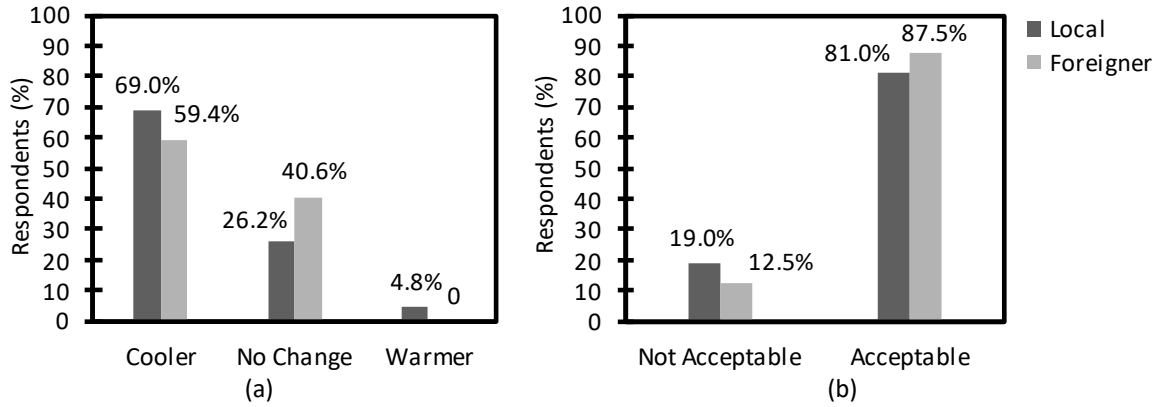

Fig. 8. (a) Preference of local and foreign respondents to change the thermal environment, and (b) their acceptance of the thermal condition

Finally, an analysis of the direct question of whether they accept the thermal condition or not for both local and foreign respondents can be seen in Figure 8(b). Even though the differences might look noteworthy, it still can be said that the percentage of foreign respondents who accept the thermal environment is higher than the local respondents, which supports the previous finding. It can be concluded that generally, local respondents find the thermal environment warmer than the foreign respondents and that the foreign respondents accept it more than the local respondents. However, are these differences considered statistically significant differences, or have they occurred due to some factors related to the current conditions of this study. Therefore, further analysis was performed to examine whether there is a statistically significant difference between the local and the foreign respondents in relation to their perception of thermal comfort. The data was tested firstly for normality, Table 4. All the obtained P-values of <0.001 were lower than the significant level, i.e., 0.05, indicating that the requirement for normality has not been met. Accordingly, the nonparametric Kruskal-Wallis test was used to test whether the distribution of the thermal sensation, comfort perception, preferences to change the thermal environment, and acceptance of the thermal condition was the same across the local and foreign respondents groups, Table 5. Based on the results, P-values ranging between 0.177 and 0.424 were obtained, which are higher than the significant value of 0.05, indicating no significant difference in the mean rank of the investigated parameters between the local and foreign respondents.

Table 4
Normality test for the distribution of the investigated variables

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Thermal sensation	0.204	106	0.000	0.925	106	0.000
Comfort perception	0.318	106	0.000	0.821	106	0.000
Preferences to change the thermal environment	0.401	106	0.000	0.652	106	0.000
Acceptance of the thermal condition	0.512	106	0.000	0.428	106	0.000

a. Lilliefors Significance Correction

Table 5
The nonparametric Kruskal-Wallis test result to check the significance of the differences between the local and foreign respondents in relation to their perception of thermal comfort

	Null Hypothesis	Sig.[a,b]	Decision
1	The distribution of the thermal sensation is the same across categories of local and foreign respondents	0.320	Retain the null hypothesis
2	The distribution of the comfort perception is the same across categories of local and foreign respondents	0.177	Retain the null hypothesis
3	The distribution of the preference to change the thermal environment is the same across categories of local and foreign respondents	0.424	Retain the null hypothesis
4	The distribution of the acceptance level for the thermal condition is the same across categories of local and foreign respondents	0.359	Retain the null hypothesis

a. The significance level is .050
b. Asymptotic significance is displayed

Based on the above, it can be said that the differences in the perception of the local and foreign residents of thermal comfort can be attributed to many factors related to the current conditions of this study, including

i. A large percentage of the foreign respondents acclimatized to Malaysia's hot, humid climate since the majority of them have been living in these conditions for more than two years (Figure 2). Long-term exposure to specific thermal conditions can form the acclimatization level, which adjusts thermal comfort requirements. As mentioned earlier, a reduction in comfort temperature was observed after ten years and was linked to the acclimatization of the occupants [28].
ii. The level of expectation to have a cooler environment when returning home might be higher with the local respondents since they were found to rely more on using AC outside their homes (e.g., work and cars) compared to the foreign respondents (Figure 3). This expectation can directly influence the respondents' votes, as indicated by Mishra and Ramgopal [27] resulting in the sense of feeling uncomfortable if not found.
iii. Clothing insulation during the survey was higher for the local respondents than for the foreign respondents (Figure 4). Some of the variations in the comfort acceptable range of the occupants was linked to clothing [22].
iv. Activities of the local respondents for the last hour before the survey were higher (i.e., cooking, house cleaning, hand working) with a metabolic rate of 1.6-3.4 met compared to the foreign respondents' activities (i.e., seated, lying, reading, writing) with the metabolic rate of 0.7-1 met (Figure 5).
v. More than 45% of the local respondents were Chinese (Table 2), who preferred lower temperatures compared to the others (i.e. Malays and Indians), as mentioned in [40-42].

4. Conclusions

In conclusion, this research was conducted to investigate the possible difference in the thermal comfort perception that might occur between the local and the foreign residents due to the influence of the individual and contributing factors that are linked to their thermal, cultural and behavioural backgrounds. It can be said that the foreign respondents found the thermal environment more acceptable compared to the local respondents and were more tolerant to warm conditions. However, although the descriptive analysis showed differences between the two groups, the statistical analysis indicated that these differences were not statistically significant. Hence, these differences can be attributed to many factors related to the current study, including; acclimatization of the foreign respondents, the expectation of the local respondents for cooler conditions, higher clothing insulation and activities level for the local respondents, and ethnicity of the local respondents.

This research is preliminary work to investigate the existing differences in thermal comfort perception between local and foreign individuals. For future research, a large-scale investigation might be required with a deep analysis of the role and influence of the contributing factors on the thermal sensation of different gropes.

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