REGULAR ARTICLE

IMPACT OF BUILT ENVIRONMENT ON THERMAL PERCEPTIONS AMONG OFFICE WORKERS IN TROPICAL LOW CARBON CITY: A PHYSICAL INACTIVITY AWARENESS ASSESSMENT

Nur Dalilah Dahlan[1*], Mainur Kurmanbekova[1], Zalina Shari[1] and Amirudin Abdul Aziz[2]

[1]Department of Architecture, Faculty of Design and Architecture,
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[2] Consultation, Research and Development Department, National Institute of Safety and Health,
Lot 1, Jalan 15/1, Seksyen 15, 43650 Bandar Baru Bangi, Selangor, Malaysia

* Corresponding author:
nurdalilah@upm.edu.my

ABSTRACT

Majority of city dwellers do not engage in regular physical activities due to their built environments that are designed to favour travel by motor vehicles. Data from the Ministry of Health, Malaysia revealed 73% of the total deaths recorded were due to Non-Communicable Diseases (NCDs), of which, approximately 35% included Malaysians belonging to the working population (< 60 years). The first objective of this study was to investigate the physical inactivity among office workers through their perceived thermal hindrances on exposure to transient thermal conditions at three different building sites in Putrajaya. The second objective was to assess the awareness level of respondents regarding their physically inactive lifestyles. Respondents suffering from NCD were identified and their level of awareness in pursuing an active lifestyle was assessed. Perceived thermal hindrances that led to physical inactivity were measured by asking participants to rate their thermal sensation and thermal comfort votes at three different times of the working weekdays, namely, commuting from home to work (morning), lunch break (afternoon), and commuting from work to home (late afternoon). The results suggested that around 85% of respondents in Putrajaya were vehicle dependant that is they used private cars and motorbikes to and from work. Most of the respondents were willing to improve their health by walking more but expressed that the midday heat and natural humidity of the tropical weather coupled with the lack of shaded paths were partially reasons for them to opt for motor vehicles as their mode of transportation in Putrajaya.

Keywords: *: physical inactivity; warm weather; office workers; thermal sensation; thermal comfort; non communicable diseases*

1. INTRODUCTION

According to the World Health Organization (2018a), government's lack of investment in building built environments that promote physical activities may contribute to further negative impacts on the community well-being and trigger Non-Communicable Diseases (NCDs). The main types of NCDs include cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes (WHO, 2018b). In Malaysia, 73% of the total deaths recorded were caused by NCDs with an estimated 35% deaths among working population Malaysians (aged < 60 years) (IPH, 2015). Rapid development of the built environment in cities suggests a positive association with most types of NCDs, as compared to that in rural areas, partly due to the decrease in physical activities (Angkurawaranon, Jiraporncharoen, Chenthanakij, Doyle, & Nitsch, 2014; Koch, 2017). Furthermore, sedentary office workers are considered the most affected population to suffer from obesity due to their lack of physical activities during working and break hours (Addo, Nyarko, Sackey, Akweongo, & Sarfo, 2015; Cheng, 2016; Heinen & Darling, 2009).

In an effort to improve societal well-being in terms of green technology adopted in the tropical built environment and health, the Malaysian government proposed The Low Carbon City Framework (LCCF) under the National Development Policy (2013). LCCF covers low carbon impact issues in four main areas, namely, urban environment, urban transport, urban infrastructure, and buildings. In relation to the National Green Technology Policy, four initiatives on sustainable development in Malaysia have been divided into five aspects: growth of energy consumption, enhancing green technology industry's contribution to the national economy, enhancing Malaysia's green technology competitiveness in the global arena, enhancing public awareness of green technology, and ensuring sustainable development through the conservation of the environment (KeTTHA, 2011). However, despite being designed to promote walking and cycling activities, residents of a Tropical Low Carbon City (TLCC), such as Putrajaya are hesitant to adopt the aforementioned mode of transportation (Abas, 2018; Siti Fatimah Hashim, Habsah Hasihm, & Shuib, 2017; Wan Omar, Patterson, & Pegg, 2011). Physical inactivity in cities have been linked with the occupants' perception of their outdoor thermal conditions, particularly with respect to walking in tropical places (Böcker, Dijst, & Faber, 2016; Chan & Ryan, 2009; Kim, Park, & Lee, 2014; Makaremi, Salleh, Jaafar, & GhaffarianHoseini, 2012; Makoto, 2009; Nasir, Ahmad, Zain-Ahmed, & Ibrahim, 2015; Pilcher, 2002; Song & Jeong, 2016).

To understand TLCC residents' hindrance towards walking or using the available pedestrian facilities, this study assumes that the respondents' walking preferences may be influenced by their thermal perceptions and the surrounding built environment of their workplace. This approach relies on testing in accordance with the following study objectives:

1) To investigate the physical inactivity among office workers in Putrajaya with respect to their thermal sensation and thermal comfort votes when walking within their workplace vicinity.

2) To assess the awareness level between the physical inactive lifestyle and its association with NCD occurrences among office workers working in Putrajaya.

2.METHODS

2.1 Selected Measured Sites

Putrajaya (2.943°N, 101.699°E) was chosen as the site study due to its implementation of the Low Carbon City Framework (LCCF) urban design concept. Accordingly, thirty eight percent of the total land area have been reserved for wetlands, green space and water body making it the pioneer green township in Malaysia (KeTTHA, 2011). Putrajaya consists of governments' administration, commercial, public buildings and recreational facilities that serve a diverse population on a daily basis. In this study, three sites in Putrajaya, namely, Ministry of Higher Education, Malaysia (B1), The Energy Commission Building (B2), and Galeria PjH (B3) were considered as the study area to investigate transient thermal comfort conditions of office workers. Transient thermal comfort conditions were assessed due to the assumption that office workers would have the tendency to walk from one place to another within their indoor to outdoor environment and vice-versa. The three study areas were chosen based on their different level of implementation of LCCF criteria, such as mixed-use development and green infrastructure settings (Moser, 2010). Local area maps indicating the locations of all three selected buildings are shown in Figure 1. Walking and cycling amenities as well as facilities situated within a 400 m radius from each of the selected buildings are illustrated in Figures 2(a) to 2(f). Four hundred meter is the recommended distance by Barton, Grant, and Guise (2003) for a person to willingly walk to his/ her destination without riding a motor vehicle (Azmi, Karim, & Amin, 2012; Butera, 2018; Murata, Campos, & Lastra, 2017).

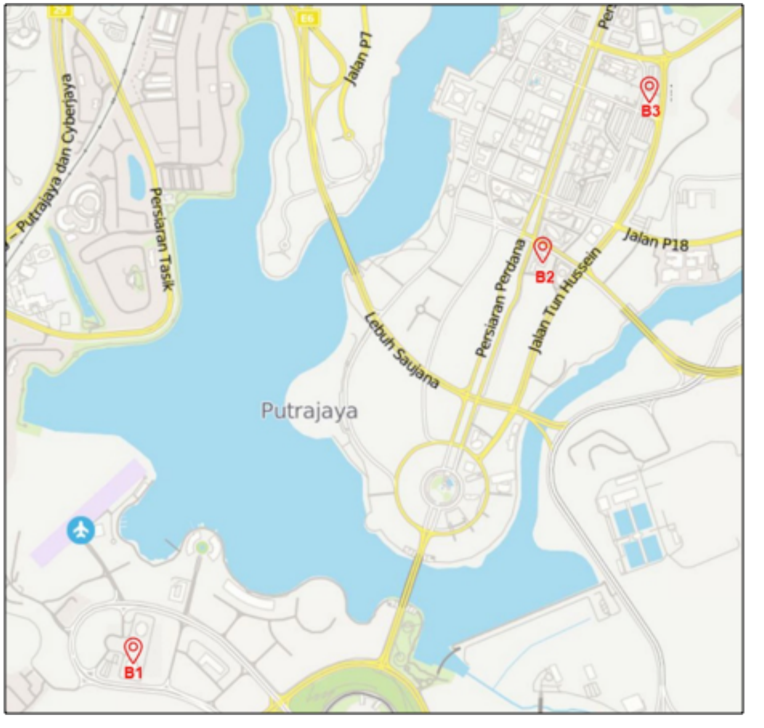

Figure 1: Local area map indicating the three selected buildings

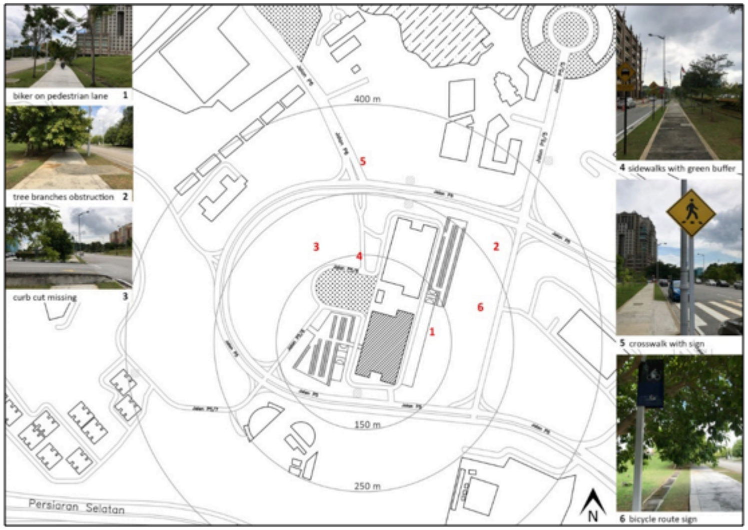

Figure 2(a): Walking and cycling amenities at B1 site

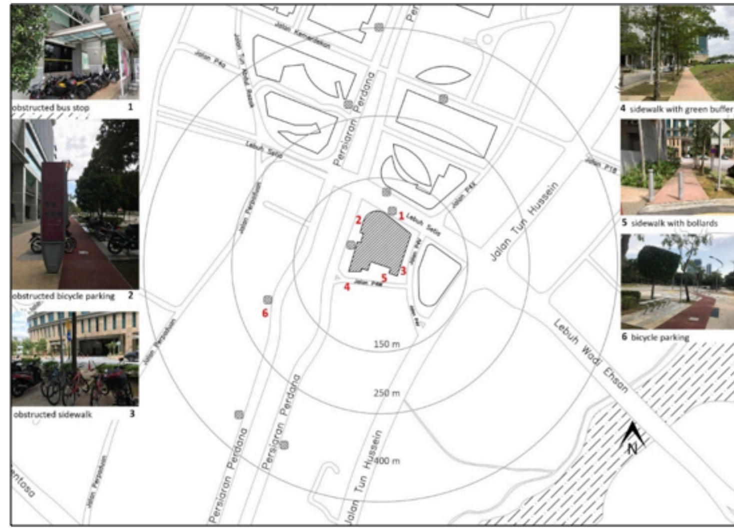

Figure 2(c): Walking and cycling amenities at B2 site

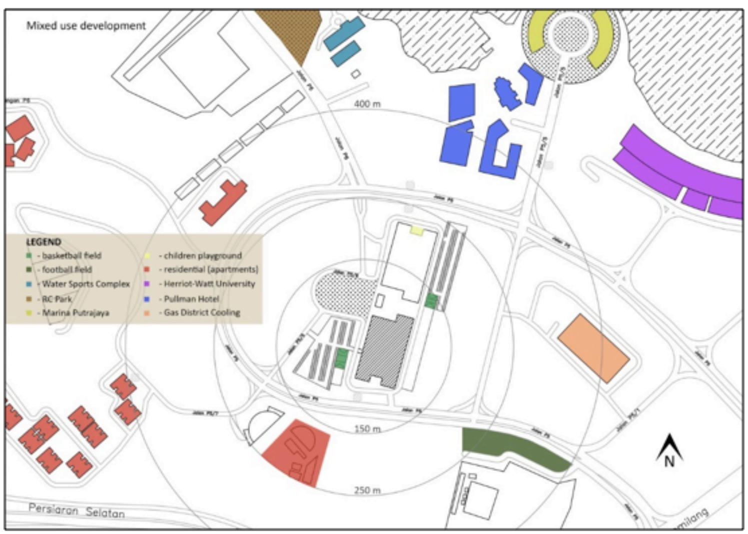

Figure 2(b): Facilities in close proximity to B1 site

Figure 2(d): Facilities in close proximity to B2 site

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Figure 2(d): Facilities in close proximity to B2 site

2.2 Research Design

This study adopted a cross sectional investigation approach, wherein microclimate monitoring and administration of questionnaires were carried out simultaneously at the three selected buildings from 23rd of July until 26th of July, 2018 during working hours, that is from 9:00 a.m. to 4:30 p.m. Permission from building managers and head of human resource officers were obtained prior to the actual field measurements.

2.3 Microclimate Monitoring

The OHM Delta Thermal Microclimate HD32.2 was used to log four basic environmental parameters known to influence thermal comfort namely, air temperature (Ta), relative humidity (RH), globe temperature (Tg), and air velocity (Va). Readings were logged every ten minutes for a period of four days. The devices were calibrated prior to actual field measurements. Air temperature and relative humidity sensor, omnidirectional air velocity probes and globe temperature sensor (type T thermocouple inside black painted 38 mm diameter globe) were calibrated using laboratory-grade instruments performed within the requirements of ISO 7730 standard (ISO, 2005). Subsequently, all four sensors were then connected to one OHM Delta data logger. Three OHM Delta data loggers were placed side by side and at a similar height of 1.5 m above the ground level. The calibration results indicated that the deviation percentage of the readings among the three devices was close to 0.4% for Ta, RH, and Tg, whereas the deviation percentage for Va was about 4%. Three measuring devices were necessary as they were placed at three different locations for simultaneous data logging. The devices were located at the pedestrian level, 1.5m above ground (Figure 3) under shaded walkways and less than 2m from pedestrians (Niu et al., 2015; Zhou, Chen, Deng, & Mochida, 2013).

(a)

(b)

(c)

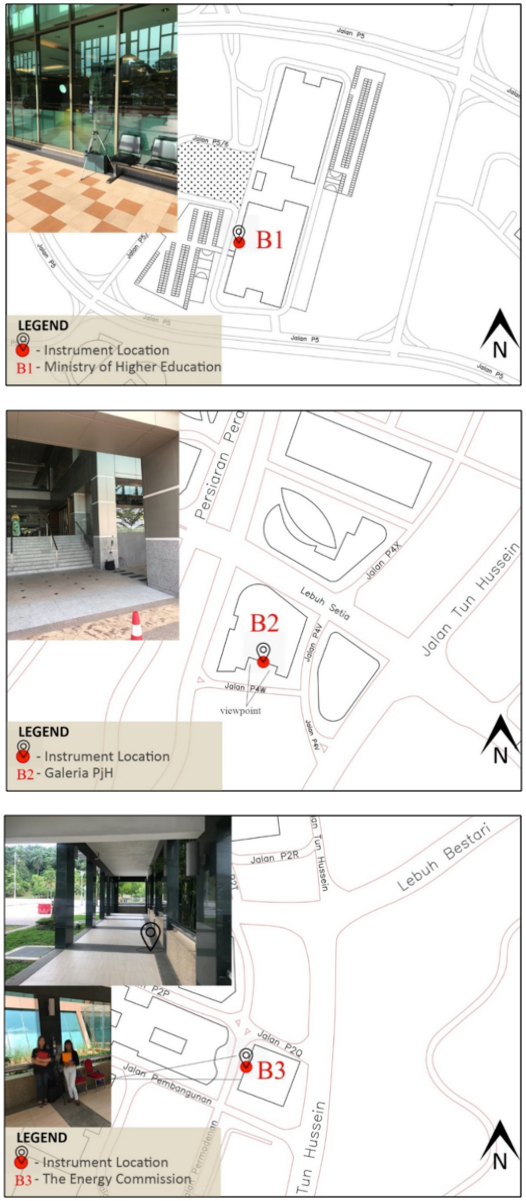


Figure 3: Instrument location at a) B1 site; (b) B2 site; and (c) B3 site

2.4 Questionnaire

Self-administered questionnaires were distributed to respondents that worked at the chosen study sites. To aid the respondents, the questionnaire contained bilingual questions that are in English along with the Bahasa Malaysia translation and a glossary of comfort terminologies. Respondents were asked for their personal information, namely, height, weight, age, gender, and health to aid in the calculation of metabolic rate to assess thermal stress in tropical climate cities (Höppe, 1999; Lin, 2009; Nasir, Ahmad, & Ahmed, 2012; Taib, 2018). The respondents' clothing ensembles were recorded and each garment was summed up in accordance to the clothing insulation (Icl) values for tropical climate ensembles provided by Havenith et al. (2015).

Thermal comfort and thermal sensation data were collected questionnaires modified from ASHRAE's 7-point thermal comfort and sensation scale (Table 1) (ANSI/ASHRAE, 2010). Respondents' perceptions for both thermal sensation and thermal comfort were based on their personal experience for the last six months when working at their respective office buildings. These questions were repeated thrice in order to evaluate respondent's thermal sensation and thermal comfort votes at different times of the day, namely, morning (7:00 – 11:59 a.m.), afternoon (12:00 – 3.59 p.m.) and evening (4:00 – 6:30 p.m.).

Table 1: ASHRAE 7-point thermal comfort and sensation scale

Thermal Sensation		**Thermal Comfort**	
hot	-3	very uncomfortable	-3
warm	-2	uncomfortable	-2
slightly warm	-1	slightly uncomfortable	-1
neutral	0	neutral	0
slightly cool	+1	slightly comfortable	+1
cool	+2	comfortable	+2
cold	+3	very comfortable	+3

The respondent's physical activity information was gathered using questionnaire adapted from the International Physical Activity Questionnaire's (IPAQ) (Craig et al., 2003). The respondents were asked regarding their commuting preference from place to place with a reference period of one week and whether they have been performing active transportation activities (i.e., walking and bicycling) during that particular week (Craig et al., 2003; Ekelund et al., 2007; Papathanasiou et al., 2009; Rivière et al., 2016). Respondents were also asked whether they reside within 400m from their workplace and their mode of commute to work (Adams, Bull, & Foster, 2016). Commuting modes were divided into four that is motor vehicle (car/motorcycle), public transportation, bicycle, and walking (Figure 5). Subsequently, the awareness level on risks of NCD among urban dwellers when physical activities are neglected was assessed (Booth et al., 2012; Müller-Riemenschneider et al., 2013)

2.5 Sampling Method

Purposive sampling technique was applied to the samples of sedentary office workers performing clerical works at the three selected buildings. Sample size of 430 respondents was determined after obtaining the total population of sedentary office workers from the selected buildings with a +/-5% margin of error and a 95% confidence interval using the Raosoft Sample Size Calculator (Raosoft, 2004).

2.6 Data analysis

Descriptive analyses were used to obtain insights into individual characteristics and environmental monitoring results. One-way ANOVA test was used to determine mean differences in the thermal sensation votes (TSV) and thermal comfort votes (TCV) among respondents at three different times of the day. Cronbach's alphas for TSV and TCV at three different times at of the working weekdays (i.e., three items each vote) were found to be acceptably reliable with $\alpha = 0.74$ and $\alpha = 0.76$, respectively. One-way ANOVA tests were also useful in identifying mean differences in walking behaviours observed between the genders, age groups, and body mass index (BMI) of the respondents at three different building sites. Statistical tests were conducted with less than 5% significance level ($p < 0.05$). Pearson correlation was computed to see the relationship between variables. All data were analysed using the statistical software IBM SPSS Statistics v20.

3.RESULTS

3.1 Meteorological Monitoring

Figures 4a, 4b, and 4c show the meteorological measurements of Ta, RH, and wind velocity (Va), respectively, that were recorded from 9 a.m. to 4.30 p.m. throughout the four-day field measurement period from 23rd to 26th July, 2018. A mean temperature difference of approximately 1 K was detected among the three sites, particularly from 9:00 to 9:30 a.m. It was believed to be due to the building's orientation, façade material properties, structure of verandas, and placement of measuring instruments.

B2 building has a quadrangle form with a prolonged and fully glazed west side that absorbs more daily solar radiation due to the high angles of the sun in the tropics (Qaid & Ossen, 2015; Sharmin, Steemers, & Matzarakis, 2015). Vitreous enamelled steel sheets, having a high reflective value of 0.57 (Riley, Cotgrave, & Farragher, 2017), were used as a façade material at pedestrian level for B2, thus increasing outdoor human thermal stress (Erell, Pearlmutter, Boneh, & Kutiel, 2014). The OHM delta instrument was placed in the south direction near the main entrance at B2 with maximum daylight penetration. However, the remaining two devices located at B1 and B3 were placed at the west side of the buildings and close to their main entrances. Therefore, there was a distinctive difference in Ta among buildings due to morning and afternoon sun exposure (Figure 4a).

Relative humidity varied the most between B1 and B2, with the difference between maximum and minimum relatively humidity being ~40%. Fluctuation in relative humidity was the lowest in B3, where the difference between the maximum and minimum RH approached 36%. From the plots in Figures 3a and 3b, it can be clearly seen that Ta and RH produced opposing readings, such that an increase in Ta decreased the RH level. This can be explained by the role of water vapour in ambient Ta acting as a source of moisture content. B2 showed the highest mean RH levels throughout the study period compared to other two buildings (Figure 4b). This was probably due to the proximity of man-made water bodies running through the area through the west and east side of the building within a 480 to 580 m radius.

Air velocity demonstrated a maximum reading of 3.9 m/s at B2, with the highest mean Va due to its large cross-ventilated ground floor atrium design. The difference in mean wind speed between B2 and B3 was marginal as both of these areas maintain higher height to width ratio, permitting the wind to permeate as compared to B1 (Figure 4c). B1 site showed the least mean Va value because of the deserted urban layout within 300 m radius of the instrument and the absence of proper vegetation to improve the air velocity.

(a)

(b)

(c)

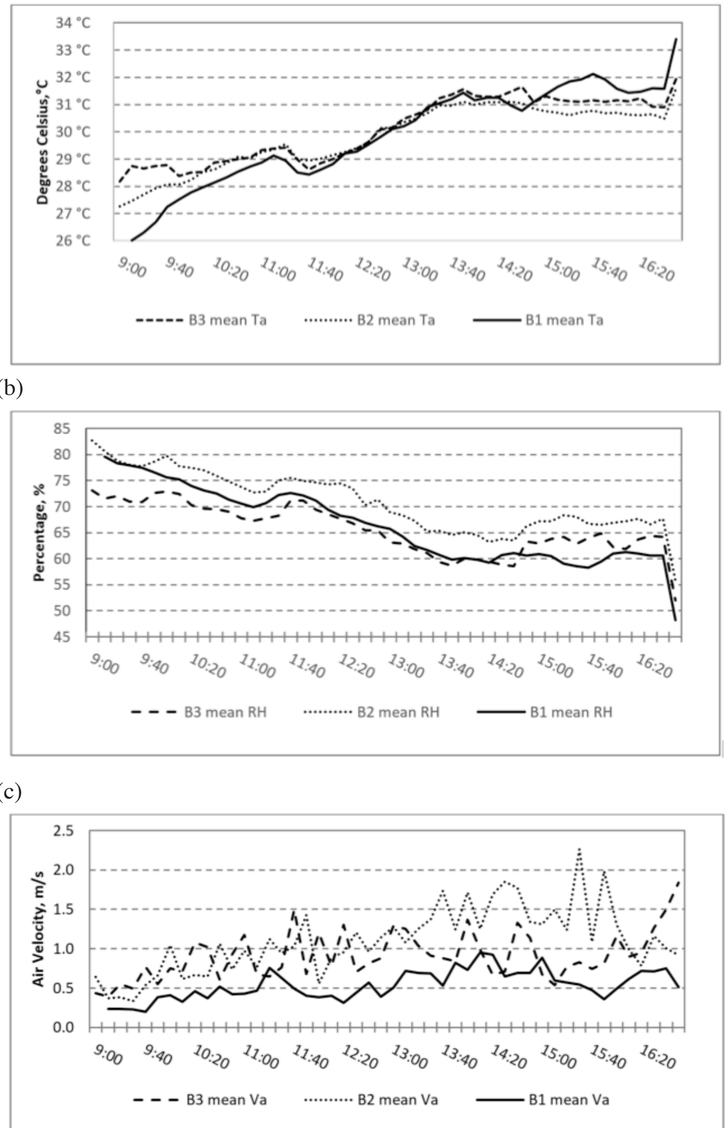


Figure 4: a) Mean Ta (°C); (b) Mean RH (%); (c) Mean Vs (m/s) during field measurements from 23rd to 26th July, 2018

3.2 Demographic and Personal Details

Three hundred and ninety-one respondents from the three selected building sites, namely, B1 (n = 166), B2 (n = 75) and B3 (n = 150) participated in the field survey. There were 10% invalid responses out of the calculated sample size of 430. There were more female (63%) respondents than male (37%). In terms of the age group, 35% of the respondents were between the ages of 31 to 35, 23% were between 36-40 years, and about 20% were within the 26-30 year age group. The remaining 22% of the respondents were below 25 (9%) and above 41 years (13%)

Almost half of the total respondents (47%) were found to reside in Putrajaya, whereas 53% of the respondents were non-Putrajaya residents. Among the respondents residing in Putrajaya, 27% were from B1, 24% from B2, and 6% from B3. 85% of the respondents were vehicle dependent and used private cars and motorbikes to reach their destinations (Figure 5a). Moreover, 81% of TLCC workers never walked to work and 90% never cycled to work for more than 15 minutes (Figure 5c and 5d). In addition, 30% used public transport, whereas remaining 70% did not (Figure 5a).

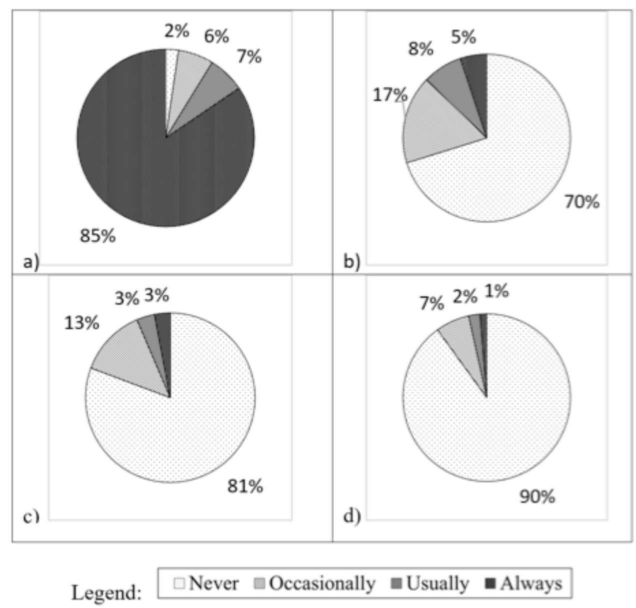


Figure 5: Total number of respondents commuting via: a) motor vehicle; (b) public transport; (c) walking; and (d) bicycle

The percentage of respondents found to be free from NCDs (i.e. based on findings from the self-reported instrument) at the three sites was 85%. The remaining respondents claimed to have been suffering from at least one type of NCDs, namely, cardiovascular (n = 5), diabetes (n = 6), hypertension (n = 10), chronic respiratory disease (n = 2), high cholesterol (n = 9), and others (n = 6), such as, arthritis, chronic kidney diseases, and eczema. Also, some respondents (n = 26) stated to have contracted more than one type of NCD.

Figure 6 represents the self-reported BMI of the respondents from the three selected sites. In total, half of the population across the three sites showed normal BMI of 18.5 to 25 kg/m2, whereas 29% were overweight (25 to 30 kg/m2), 11% were obese (above 30 kg/m2), and 10% were underweight (below 18.5 kg/m2).

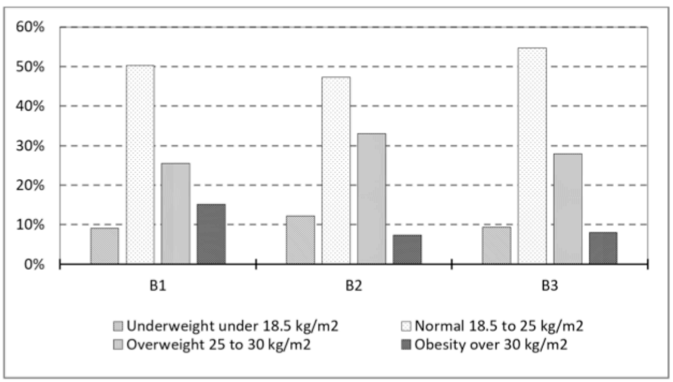


Figure 6: BMI percentage per site

Mean clothing ensemble insulation values gathered from all three sites suggest that male Icl was higher (M = 1.3, SD = ±0.3), which commonly contained men's briefs, work shirt, work pants, socks, and shoes, compared to females (M = 1.1, SD = ±0.3) who typically wore underwear, long sleeved shirt, suit pants or skirt, hijab, socks, and shoes. Calculations using T-test indicate significant mean difference between genders in all three sites, as follows:

i) B1: males (M = 1.39, SD = ±0.61) and females (M = 1.15, SD = ±0.26), $p < 0.01$,

ii) B2: males (M = 1.46, SD = ±0.27) and females (M = 1.07, SD = ±0.43), $p < 0.01$, and

iii) B3: males (M = 1.28, SD = ±0.16) and females (M = 1.12, SD = ±0.31), $p < 0.05$.

3.3 Relationship between Thermal Sensation and Thermal Comfort Votes

One-way ANOVA tests were conducted to compare the TCV and TSV votes in the three selected sites at three difference times of the day, namely, morning (7:00-11:59 a.m.), afternoon (12:00-15:59 p.m.), and evening (16:00-18:30 p.m.) (Figure 7).

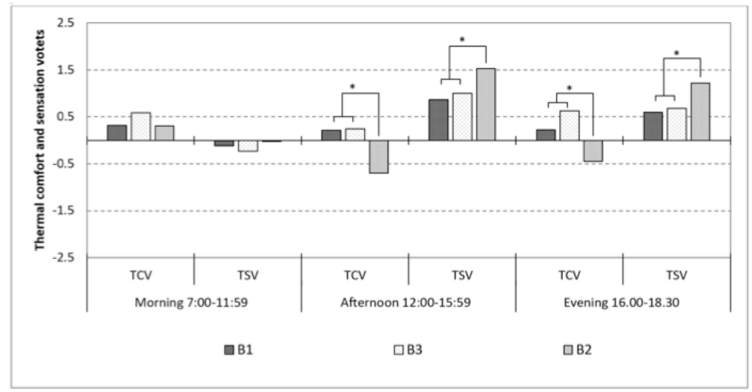


Figure 7: Mean Thermal Comfort and Thermal Sensation Votes among the three sites.
*Note: * Correlation is significant at $p < 0.01$ level (2-tailed)*

Figure 7 shows that TCV and TSV are deemed to be neutral and neither cold nor hot, respectively in all three selected sites using one-way ANOVA tests. However, there are significant mean differences between two votes in the afternoon and evening when walking outdoor. B2 respondents expressed that their thermal comfort during afternoons and evenings were low, with mean scores of -0.7 (SD = ±1.5) and -0.5 (SD = ±1.5), respectively. These results are also reflected in the respondents' TSVs, wherein, walking outdoors in the afternoons and evenings were deemed to be warm (mean = 1.5, SD = ±1.2) and slightly warm (mean = 1.2, SD = ±1.1), respectively. Post hoc using Bonferroni tests suggested that mean TCV and TSV responses from B2 respondents were significantly different in comparison to their B1 and B3 counterparts. Therefore, it can be assumed that the office workers felt that the surrounding built environment at B2 contributed to their thermal discomfort, particularly when moving from indoor to outdoor spaces during their lunch break.

3.4 Relationship between BMI and Walking

The Pearson correlation was performed to assess the relationship between the BMI status of respondents and their weekly walking patterns. The number of office workers who walked habitually on a weekly basis based on their BMI is shown in Figure 8. Although subjects with normal and overweight BMI that walked more surpassed the ones who did not, the difference in the three sites was not significant in B1 ($r = 0.095$, $n = 165$, $p = 0.224$), B2 ($r = 0.103$, $n = 148$, $p = 0.213$), and B3 ($r = -0.218$, $n = 75$, $p = 0.061$).

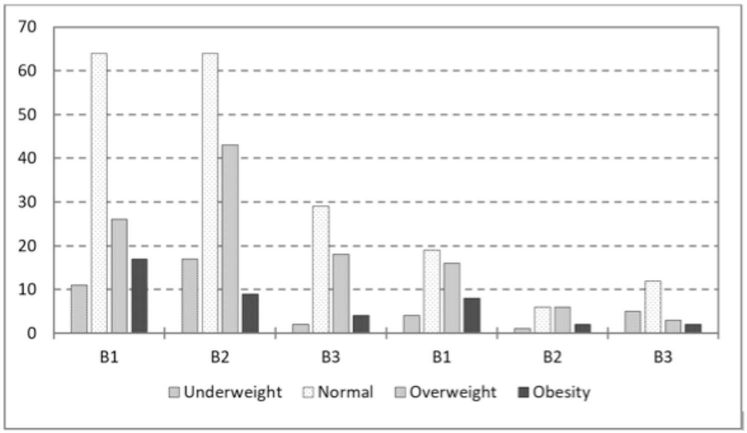


Figure 8: General weekly walking vs. BMI

The Pearson correlation was computed between the frequencies of weekly walking by office workers and their BMI status. Despite a large number of office workers stating that they walk five times per week or more across three sites, a non-significant difference was established for B1 ($r = -0.152$, $n = 165$, $p = 0.051$), and B3 ($r = 0.184$, $n = 75$, $p = 0.115$) (Figure 9). However, B2 showed a statistically significant effect ($r = -0.185$, $n = 148$, $p = 0.024$), with the Bonferroni test indicating that the mean score for the underweight group ($M = 3.61$, $SD = \pm0.778$) was higher than that for the overweight group ($M = 2.84$, $SD = \pm1.106$), suggesting that respondents who fall in underweight category at B2 walk more often compared to the overweight type.

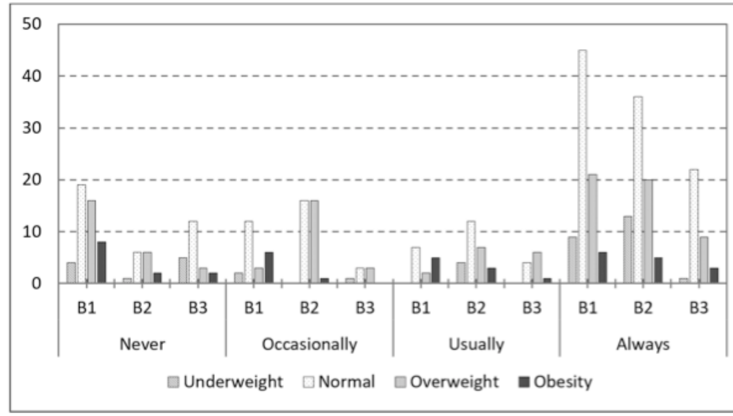
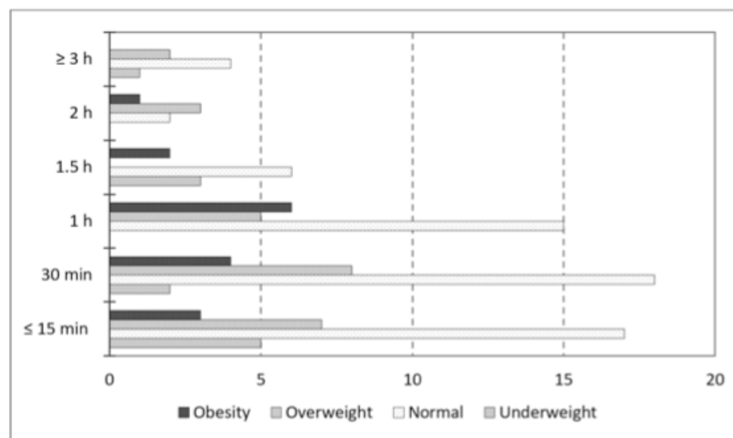


Figure 9: Moderate weekly walking vs. BMI

The relation between time spent walking per day based on the BMI status of respondents across the three study areas, that is B1 ($r = -0.062$, $n = 165$, $p = 0.431$), B2 ($r = -0.076$, $n = 148$, $p = 0.359$), and B3 (B3 $r = 0.147$, $n = 75$, $p = 0.208$) was not significantly different according to the Pearson correlation. Figures 10a to 10c show that more number of normal and overweight people spend 30 minutes or less to walk from one place to another.

(a)



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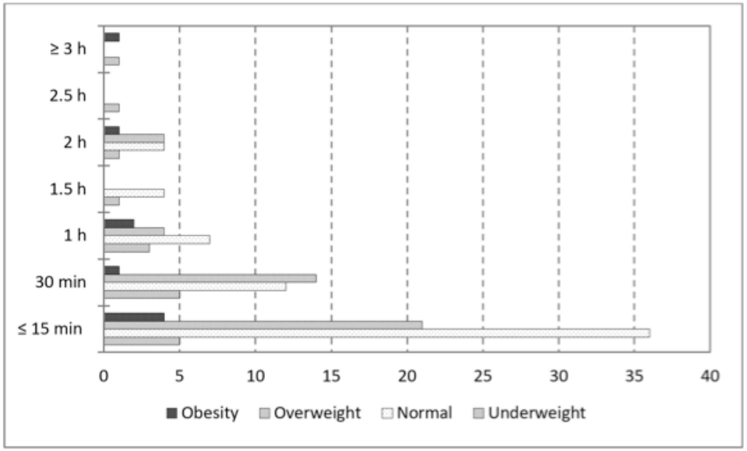

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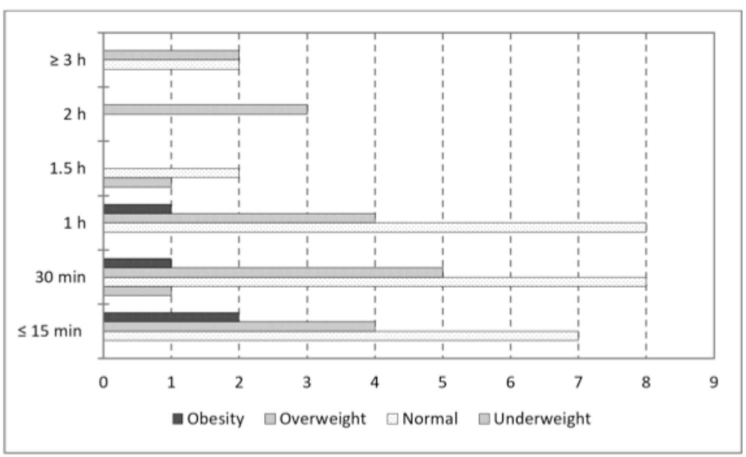


Figure 10: Time spent walking per day by respondents with respect to BMI at (a) B1, n = 165; (b) B2, n = 148; and (c) B3, n = 75

3.5 Relationship between Gender and Walking

It was hypothesized that the gender of respondents might contribute to overall weekly walking, frequency of weekly walking pattern, or time spent walking per day, but that effect might differ across office buildings selected. Generally, 79% respondents stated that they walked for at least 10 minutes per day. Referring to Figure 11, a greater number of non-walkers were observed at B1 and B3, with the number of male office workers slightly higher compared to females. Overall, almost one-fifth of respondents (22%) acknowledge that they did not walk for at least 10 minutes per day.

A 2 x 2 between-subjects ANOVA was conducted on general weekly walking, with gender and the three chosen sites being the factors. Employees from B1 (72%) and B3 (71%) sites showed lower level of weekly walking scores compared to B2 (90%) with a significant effect at $p < 0.01$ level. The influence of gender along with gender and site interaction at B2 was not significant at $p > 0.05$ level, with males (10%) and females (10%) each constituting nearly one-tenth of the overall non-walkers.

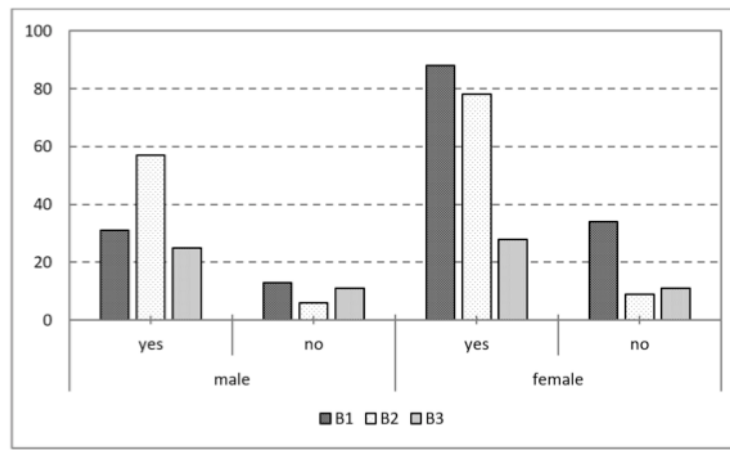


Figure 10: Time spent walking per day by respondents with respect to BMI at (a) B1, n = 165; (b) B2, n = 148; and (c) B3, n = 75

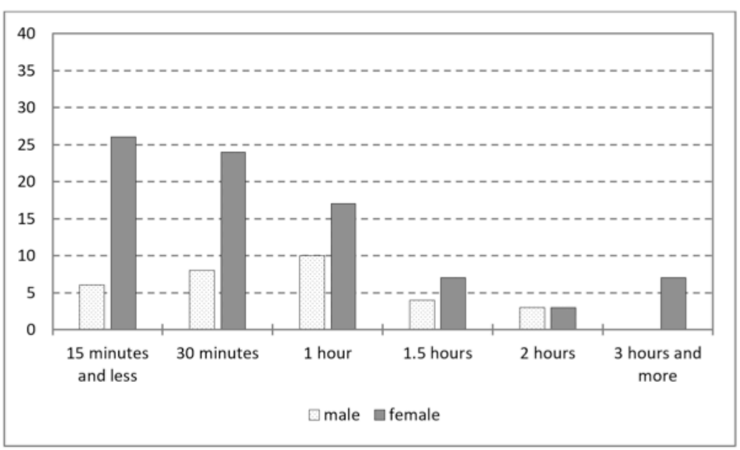
A two-way analysis of variance tested the frequency of weekly walking of males and females among respondents at B1, B2, and B3 study sites. The main effect of gender and site on frequency of weekly walking showed no significant difference at $p > 0.05$ level. The gender and site interaction were not significant at $p > 0.05$ level (Table 2).

Table 2: Mean level of frequency of weekly walking by site and gender of respondents

		B1	B2	B3
Male	M	2.82	3.18	2.92
	SD	±1.35	±1.03	±1.36
Female	M	2.78	3.01	2.67
	SD	±1.31	±1.08	±1.26
p-value		0.86	0.42	0.38

In Figures 12a, 12b, and 12c, the time spent walking per day for more than 10 minutes per trip was cross-tabulated by gender at B1, B2, and B3. It was revealed that the percentage of office-workers who walked for 15 minutes or less during the day at B1 and B3 were 19% and 17%, respectively, whereas almost half of the B2 respondents walked for 15 minutes or less per day. Overall, respondents walked one hour or less across the three different sites, with females surpassing males at the three study areas. Subsequently, the time spent walking per day was analysed in a two-way mixed factorial ANOVA, with the chosen study areas manipulated as a within-subjects variable and gender as a between-subjects variable.

(a)



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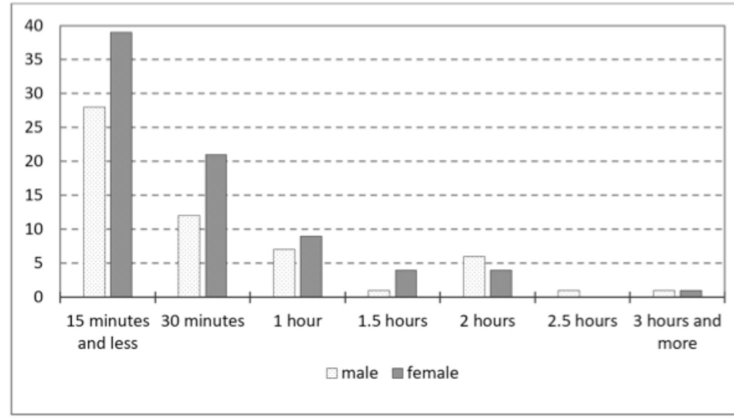

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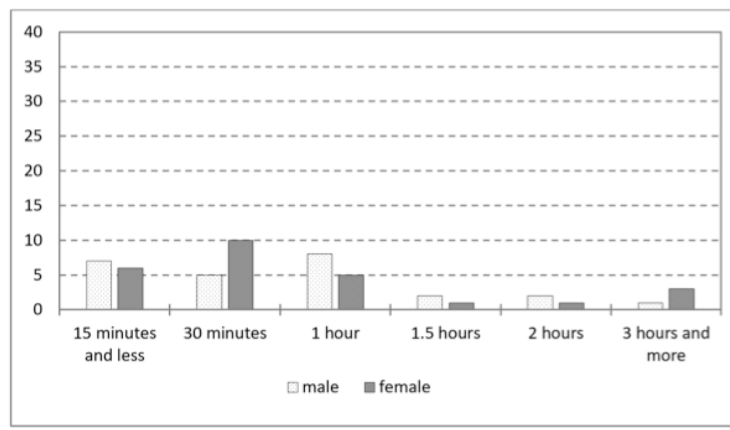

Figure 12: Time spent walking per day in reference to gender at (a) B1; (b) B2; and (c) B3

3.6 Relationship between BMI and Thermal Sensation Vote Outdoor

A two-way analysis of variance was conducted to compare the main effects of respondents' BMI and working neighbourhood and the interaction effect between BMI and working area on the TSV outdoors. BMI comprised of four levels (underweight, normal, overweight, and obesity). The two main effects were statistically significant at the $p < 0.01$ significance level; however, the interaction between the employees' BMI and their working area was not statistically significant $F(6,376) = 0.744$, $p = 0.61$. The main effect for BMI yielded and F ratio of $F(3,376) = 4.73$, $p < 0.01$ indicated a significant difference between underweight (M = .88, SD = ±1.20), normal (M = 1.25, SD = ±1.26), overweight (M = 1.12, SD = ±1.32), and obesity (M = 1.67, SD = ±1.16) levels. A post-hoc Tukey's HSD test showed that obese respondents had significantly higher TSV scores (feeling warmer outdoors) than the underweight ones, at a .05 level of significance. The main effect of chosen sites yielded an F ratio of $F(2,376) = 5.60$, $p = .004$, indicating that the effect of the site was significant, such that B1 (M = .92, SD = ± 1.30), B2 (M = 1.41, SD = ±1.17), and B3 (M = 1.51, SD = ±1.28). A post-hoc analyses using Tukey HSD test were conducted on all the possible pairwise contrasts, with B1 and B2, and B1 and B3 pairs showing significance at a .01 level (Figure 13).

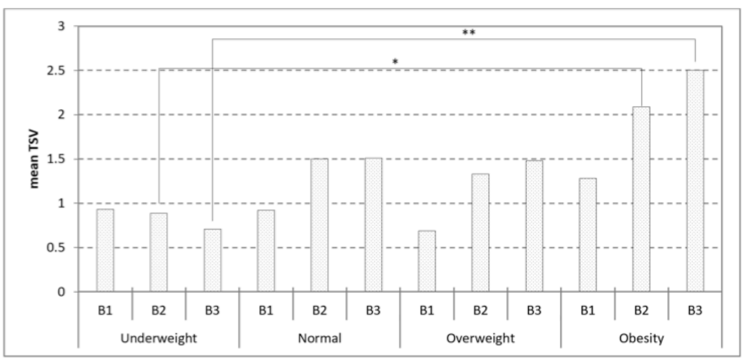

*Figure 13: Mean Thermal Sensation Votes by their BMI across three sites. Note: Correlation is significant at '**' $p < 0.01$ level, '*' at $p < 0.05$ level (2-tailed)*

3.7 Relationship between Gender and Thermal Sensation Vote Outdoor

Males (n = 44, M = .82, SD = ±1.3) and females (n = 122, M = .96, SD = ±1.3) in B1 were associated with approximately equal outdoor TSV (-3 = cold, to +3 = hot) in the area. However, males in B2 (n = 63, M = 1.10, SD = ±1.0) and B3 (n = 36, M = 1.28, SD = ±1.5) were associated with numerically smaller TSV. To test the hypothesis that gender was associated with statistically significant different mean TSV, an independent sample t-test was performed, and it was associated with a statistically significant effect only on B2 at $p < 0.01$ level. Thus, females felt warmer outdoor near their working area compared to males (Figure 14).

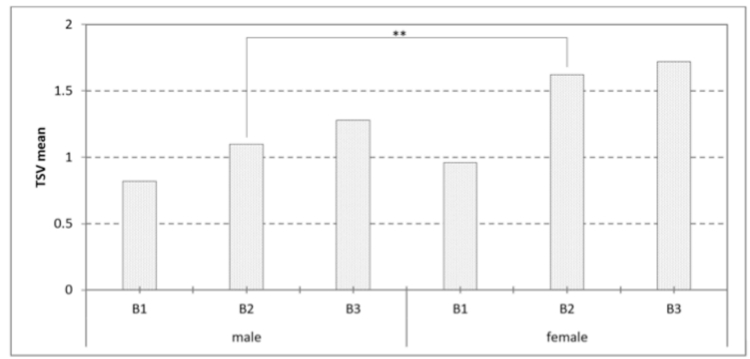

*Figure 14: Outdoor Thermal Sensation Vote bar graph. Note: Correlation is significant at '**' the $p < 0.01$ level (2-tailed)*

3.8 NCD Awareness in Relation to Willingness to Walk

The Pearson correlation was performed to assess the relationship between the NCD status of respondents and their physical inactivity awareness. The number of office workers' awareness level that physical inactivity leads to NCDs is shown in Figure 15. Although most of the subjects with NCDs agreed that physical inactivity led to diseases, the difference between the awareness level between respondents with and without NCDs in B1 (n = 166, r = -0.04, p = 0.59), B2 (n = 150, r = 0.05, p = 0.58), and B3 (n = 75, r = 0.05, p = 0.66) was not significant.

Furthermore, the Pearson correlation was performed to assess the relationship between the NCD status of respondents and their willingness to walk more. The number of office workers who were willing to walk more is shown in

Figure 16. Meanwhile, 17.4% of overall respondents could not decide whether they would like to walk more or not. Five percent of the office workers who did not suffer from NCDs were not ready to change their lifestyle. Even though 86% of the respondents with NCDs showed their willingness to walk and adopt an active lifestyle across three sites, no significant mean differences were calculated between B1 ($n = 166$, $r = 0.04$, $p = 0.59$), B2 ($n = 150$, $r = 0.02$, $p = 0.83$), and B3 ($n = 73$, $r = 0.16$, $p = 0.18$).

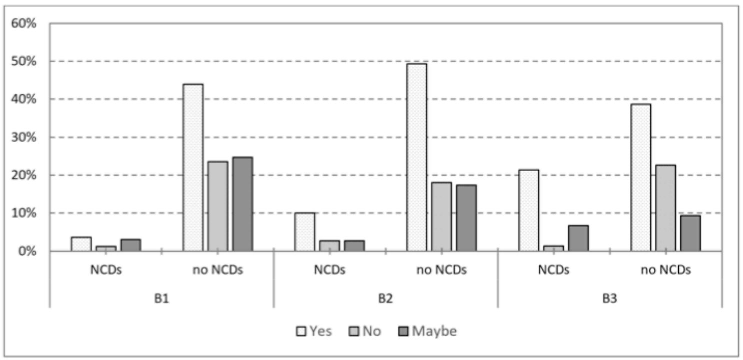

Figure 15: Percentage of respondents with NCDs with an awareness of physical inactivity vs. without NCDs

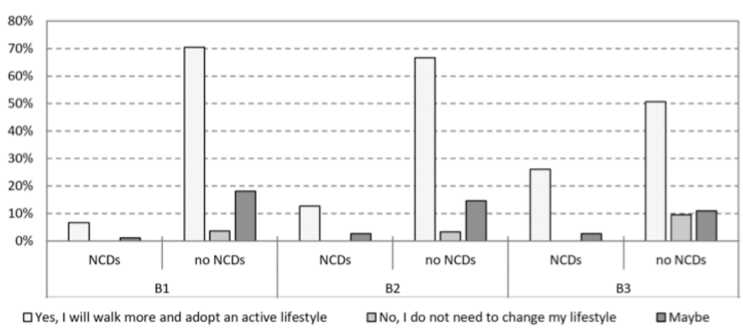

Figure 16: Percentage of respondents with NCDs with willingness to walk more vs. without NCDs

4. DISCUSSION

This study investigated the physical inactivity among sedentary office workers, particularly through the lack of walking in relation to their perceived thermal judgements (via thermal sensation and thermal comfort) when exposed to transient indoor-outdoor movements at three different building sites in Putrajaya. Based on the microclimate monitoring on site, it was observed that the lack of a more pedestrian-friendly pavement in B2 made respondents feel much warmer and thermally discomfort during the afternoon and evening, as compared to B1 and B3 (Figure 6). Moreover, a higher mean Icl value of 1.46, based on male respondents in B2, related to a higher indoor-outdoor temperature difference during the field measurement. Unexpected rise in temperatures and stunted evaporative heat loss from the human skin have been reported to cause thermal discomfort in moving through spaces with temperature step-changes (Dahlan & Gital, 2016; Fountain, Arens, Xu, Bauman, & Oguru, 1999; Hitchings & Shu Jun Lee, 2008; Jing, Li, Tan, & Liu, 2013).

Influencing factors, such as BMI, gender, and Icl were tested against the modes of transportation in hot and humid weather. BMI level was found to influence the respondents' thermal sensation votes at a 0.05 level of significance, with obese respondents ($BMI \geq 30$ kg/m2) reported feeling warmer as opposed to underweight respondents ($BMI \leq 18$ kg/m2). Similarly, Habibi, Momeni, and Dehghan (2016) also found that overweight people are more susceptible to higher temperatures that may result in heat stress, thus limiting their outdoor physical activities (Alharbi & Jackson, 2017; Wagner, Keusch, Yan, & Clarke, 2019). However, the finding in this study is not in agreement with the results of Tuomala et al. (2013), which showed that when BMI increased, the thermal sensation value decreased in males ($M = 0.09$, $SD = \pm 1.1$) and females ($M = 0.10$, $SD = \pm 1.2$) using the Human Thermal Model, which takes into consideration both true anatomy (body part level tissue distribution) and physiology (thermoregulation) models . In addition, the previous model was also developed using samples that were acclimatized to temperate climate (Holopainen, 2012; Takada, Kobayashi, & Matsushita, 2009), which is in contrast with samples from this study.

In this study, when asked to rate their thermal sensation while walking within close proximity of their office building, there was a significant mean difference at $p < 0.01$ level between male and female respondents. In spite of male workers having to wear clothing ensembles (Icl) ($M = 1.46$, $SD = \pm 0.3$) that are higher than the female workers' clothing ensembles ($M = 1.07$, $SD = \pm 0.4$), females at B2 felt warmer outdoor near their working area compared to their male counterparts. This result is in accordance with a study done by Lam, Loughnan, and Tapper (2018) in Melbourne, Australia where females were found to be less tolerant to the hot weather compared to males. Since females have a greater sensitivity to changes in thermal environment, they need higher individual temperature control and adaptive actions (Karjalainen, 2012; Tuomaala et al., 2013). The observed Icl value gathered from the male respondents was calculated to be approximately double the tested Icl value recommended by Havenith et al. (2015) for non-western countries, namely, 0.61. Meanwhile, the observed Icl value for the female respondents was quite similar, that is, 0.97 (Havenith et al., 2015). However, female respondents felt more uncomfortable compared to males when exposed to cold conditions and felt warmer than their male counterparts in warm conditions in spite of their ideal Icl value. This observation is in agreement with (Amindeldar, Heidari, & Khalili, 2017; Thapa, 2019). Furthermore, it was found that females presented a higher prevalence of physical inactivity in contrast to males partly due to the surrounding built environment. Previous studies have revealed that non-pedestrian-friendly built environment that impedes walking or cycling in urban areas will most likely lead to physically inactivate behaviours (An, Shen, Yang, & Yang, 2019; Farias et al., 2019; Transportation Research Board, 2005).

Respondents' awareness level in adopting an active lifestyle to improve their health was quite high for both healthy and NCD sufferers. However, when asked regarding their modes of transportation for daily trip to work, 85% of the respondents opted to use motor vehicles regardless of the provision of cycling lanes and related facilities to support walking activities available in the measured sites. This finding is also in agreement with the findings from Siti Fatimah Hashim et al. (2017) and observation by Abas (2018).

The study had some limitations. First, the cross-sectional nature of the study would not allow for cause-effect relationships to be established between the socio-demographic factors and NCD occurrences in office workers in Putrajaya. Second, the results of the study could only be generalized to office workers who use the designated pathway close to main entrance of their workplace, and were not applicable to all office workers who worked in all administrative building located in Putrajaya. A third limitation was that the self-reported questionnaire did not provide accurate estimates of BMI driven physical activity. Therefore, replication of this study using representative sample of the office worker population (local government study) is highly suggested. Due to overwhelming information observed in this article, it is decided that findings in regard to age group related investigations for this study will be reported in a separate article succeeding to the current article.

5. CONCLUSION

The warm tropical weather was established as a hindrance to walking in cities. In the case of a Tropical Low Carbon City, such as Putrajaya, introducing a culture of walking in a population that is less likely to walk more than ten minutes may be more complex than simply providing pavements and covered walkways. Moreover, respondents were aware of the impacts of the built environment on their physical activities. Most of the respondents are willing to improve their health by walking more but expressed that the midday heat and natural humidity of the tropical weather coupled with the lack of shaded paths contributed to the high rate of motor vehicle dependency in Putrajaya. Nevertheless, further studies on perceived thermal hindrances based on transient thermal comfort is recommended based on the discrepancies in male respondents' clothing insulation value found in this study in comparison to findings from controlled experiment settings.

It is hoped that the findings from this study may contribute to the National Policy on Climate Change, particularly under the premises of societal well-being and environmental protection. The outcome of this study is likely to complement the Low Carbon Cities Framework considering the aspect of pedestrian well-being as there is no specific guideline for comfortable walking distance in Malaysia's urban built environment. In addition, strategies to follow an active lifestyle through walking and other physical activities should be encouraged for the prevention of NCDs in Malaysia.

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