A study of The Thermal Comfort Perception on Campus Outdoor Urban Spaces- Special Reference to Hot Arid Climatic Zones

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Abstract
Outdoor spaces are considered important elements in cities as they provide a space for activities which enhance the livability and vitality of the city (Liang Chen, Edward NG, 2012). Well-designed outdoor spaces encourage more people to use them which will be beneficial from different aspects; environmental, economic, social and physical aspects.
Urban outdoor spaces are considered significant elements in university campuses; which makes thermal comfort in these spaces very important to be achieved. Outdoor microclimate is an important issue affecting the quality of outdoor spaces. Outdoor spaces have very rich microclimatic characteristics that affect users' thermal comfort and thermal comfort perception. Users' needs to reach thermal comfort in outdoor spaces vary according to gender, age and other factors. This paper studies users' approach of the thermal environment in outdoor spaces in university campuses.
The case study has chosen, ten different spots in the British University in Egypt where the measurements and survey were conducted. The purpose was to measure the level of users' perception and preference of the surrounding thermal environment. The devices used for the measurements were Anemometer, Humidity meter, Thermometer, Globe thermometer and CM6B Pyranometer. The measurements were taken over one year, from May 2014 till April 2015. The measurements were taken on intervals as indicated, morning from 9am to 11 pm, midday from 12 pm to 2 pm and afternoon from 3 pm to 4 pm, the measurement time was chosen through the academic year and the occupation hours of the campus. The data from the measurements and surveys were gathered in order to determine the neutral physiologically equivalent temperature (PET) which was determined by analyzing the relationship between thermal sensation votes (TSV) and PET. The findings showed that respondents in BUE campus were sensitive to the variations of the PET. It is due to, every 3.9 C of PET, means that thermal sensations have changed one unit in BUE campus, Cairo, Egypt.

Keywords
Thermal Comfort; University Campus; British University in Egypt; Hot arid Zones.

Introduction
Buildings are the shelter for humans and the main separator from the outdoor envieornmental factors. Urban spaces are considered important elements in cities as they are great contributors to the livability of cities as well as accommodating some activities and the pedestrian traffic

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(Liang Chen, Edward Ng, 2011). In the past few decades, the design of urban spaces grew of great importance as it became a design and urban planning goal (Maruani, T., Amit, C., 2007). Multiple predictions stated that by the year 2025, 60% of the global population will be living in cities which need urban expansion. Urban expansion usually causes urban heat islands and the declination of green public spaces (Min Xu, et, al., 2018). The qulaity of green urban space and outdoor spaces generally has a significant impact on users of these spaces. Recent trends of architecture and urban design have been encouraging people to spend more time outdoors. People are exposed to multiple environmental factors that directly affect their human physiological state which in return affect their thermal comfort (Zhaosong Fang et, al., 2018). Urban environments and outdoor spaces are greatly affected by climate change which caused a lot of challenges. Heatstrokes caused by high temperatures are great risks. High dense urban spaces are always accompanyed by urban heat islands which mean higher temperatures in the built areas than rural areas (Karakounos, A. Dimoudi, S. Zoras, 2017). Controlling the outdoor environment in outdoor urban spaces and considering the users' thermal comfort can create more successful outdoor spaces that achieve a high level of users' satisfaction.

Nomenclature

ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
PET	Physiological Equivalent Temperature
TSV	Thermal Sensation Vote
PMV	Prediced Mean Vote

Human Thermal Comfort in Outdoor Spaces

The traditional thermal comfort theory depends on a model where the production of heat equals the heat losses while maintaining the temperature of the core body at 37°C (Nikolopoulou, M. et al., 2001).

Achieving human thermal comfort in outdoor spaces is an important matter as these spaces accommodate multiple activities which achieve urban vitality and livability. The quality of the outdoor spaces is determined by the outdoor microclimate. The users of outdoor urban spaces are in a direct contact with all the environmental variations in the microclimate such as wind, sun and shade (Liang Chen, Edward Ng, 2011). Thermal comfort of outdoor spaces' users is affected by multiple personal factors as well, such as adaptation, gender and culture. Shading is one of the factors affecting thermal comfort in outdoor spaces, multiple studies that were conducted have indicated that shading levels affect the thermal environment and increase the gathering of people in the outdoor areas (T.P. Lin, et al, 2013).

Thermal Sensation Vote (TSV)

Thermal comfort depends on a large number of factors besides the equations of heat transfer and other physics equations. Thermal comfort perception differs due to a large number of factors. The human factor is effective in the calculation and predicting of human thermal comfort as it depends on multiple factors such as the activity, clothing level, air temperature, humidity and air flow velocity. The Prediced Mean Vote (PMV) 9s the average thermal sensation response of a large number of subjects using the ASHRAE thermal sensation scale which is based on the comfort equation of Fanger. PMV predicts the mean (TSV) for a large group of people (Honjo, Tsuyoshi, 2009).

Calculation of Physiological Equivalent Temperature (PET)

Physiological Equivalent Temperature is the air temperature where the human body balance is maintained with skin and core temperatures that are equal under the studied conditions. (Höppe and Mayer 1987). Physiological equivalent temperature is a parameter that describes the thermal perception of people biometeorologically (Nikolopoulou, Marialena., 2011).

Methodology

Thermal comfort conditions examination needs to perform field survays in outdoor urban spaces, in order to accumlate substantial data for this study to determine outdoor thermal comfort in BUE campus, Cairo, Egypt. “It has been authorized that field studies of thermal comfort are conducted in actual thermal environment conditions and involve larger and diverse samples of real occupants” (de Dear, R.J., 2004).

Field surveys in this study included :

- Structured questionnaire and interviews: to deal with respondents in terms of thermal preference, sensation, activity level and clothing during the survey.
- Field measurements: to measure all climatic parameters, which influence outdoor thermal comfort by using several insturments such as Anemometer, Humidity meter, Thermometer, Globe thermometer and CM6B Pyranometer.
- Observation sheet: to note environmental conditions in the students’ surrounding. Besides, to collect data about (environmental parameters , date and time, , respondents’ activity and clothing), this procedure is conducted to notice anything that may influence the results and for double checking.

2.1 Study area

Ten different spots in the British University in Egypt where the measurements and survey were conducted as shown in Figure (1), from May 2014 to April 2015 where field surveys are being carried out . The study areas are represented in places that have spots woth seats for food, relaxing, meeting friends, studying, and activity practicing. Study areas are shown in Figure (2) and the description of study areas are presented in Table (1).

FIGURE (1): POINTS OF THE STUDY AREAS AT BUE CAMPUS
SOURCE: THE AUTHOR

Table (1) Descriptions of each study area in BUE campus

Study area		Zone Number	Description
Entrance space		1	It is in the west part of the campus, surrounded by three buildings, with palm trees, Shrubbery and grass.
Main plaza		2	It is in the west part of the campus, surrounded by a building from one edge, trees and grass.
Faculty of engineering	Front yard	3	It is in the north part of the campus, surrounded by trees and grass.
	Back yard	4	It is in the north part of the campus, surrounded by trees and grass.
	In between spaces	5	It is in the south part of the campus, surrounded by Shrubbery and grass.
Main plaza 2 (food court and theater)		6	It is in the north part of the campus, surrounded by trees and grass.
Playgrounds		7	It is in the north part of the campus, surrounded by trees and grass.
Faculty of nursing	Front yard	8	It is in the east part of the campus, surrounded by trees and grass.
	Back yard	9	It is in the east part of the campus, surrounded by trees and grass.
	In between spaces	10	It is in the east part of the campus, surrounded by Shrubbery and grass

FIGURE (2): IMAGES OF THE STUDY AREAS AT BUE CAMPUS … SOURCE: THE AUTHOR

2.2 Research Sample

Total questionnaires no. was 144 which were collected during the study, but only 130 questionnaires were valid, 14 of them were missing samples as shown in figure (3).

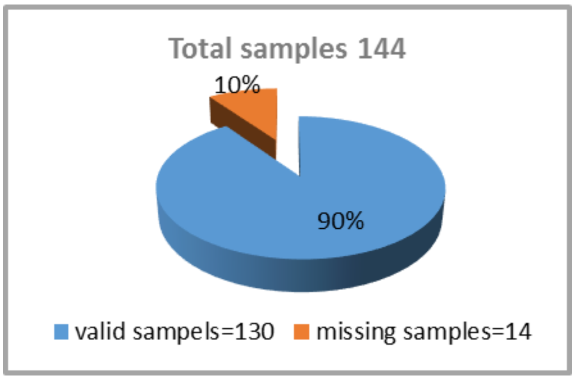
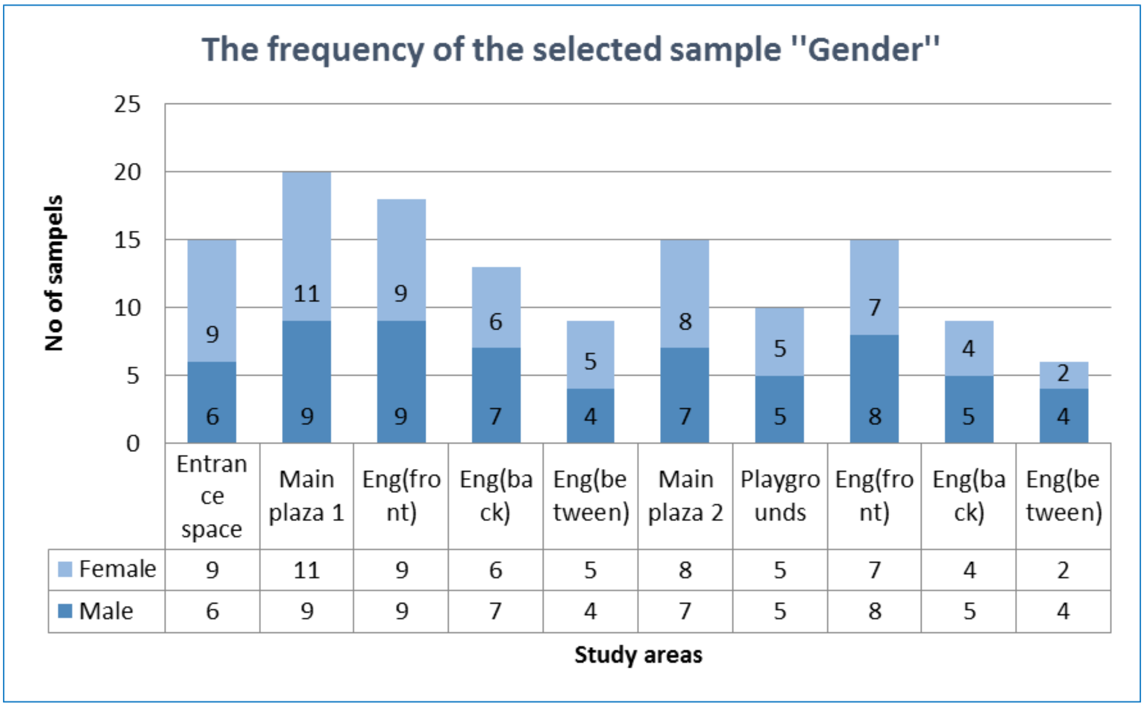


FIGURE (3): RESEARCH SAMPLE
SOURCE: THE AUTHOR

2.2.1 Gender of the sample

Total sample of males is 64 while total sample of females is 66, data of the samples is shown in figure (4) in detail.



	Entrance space	Main plaza 1	Eng(front)	Eng(back)	Eng(between)	Main plaza 2	Playgrounds	Eng(front)	Eng(back)	Eng(between)
Female	9	11	9	6	5	8	5	7	4	2
Male	6	9	9	7	4	7	5	8	5	4

FIGURE (4): GENDER DISTRIBUTION OF THE RESEARCH SAMPLES IN THE SURVEY

2.2.2. The respondents characteristics

Total of valid respondents was 130, 66 of them were famles and 64 were males, minimum age was 17 years old but maximum was 27 with avarage 22 years old. The minimum Length of study time in BUE campus was 2 years and maximum was 5 years. Maximum clo value was 56 and minimum value was 15. The number of males was 64 representing 49.2% of the sample and the number of females was 66 representing 50.8% of the sample. The age minimum is 17 years old and the maximum is 27 years old with an average of 22 years.

2.3 Instruments

Field measurements instrumentation

- Anemometer, humidity meter, thermometer (LM-8102): This instrumentation shown in figure (5), measures of air temperature, humidity, and wind speed. Anemometer which uses low-friction ball bearing mounted wheel design that provides high accuracy, and humidity meter which uses high precision humidity sensor with fast response time.
- Globe thermometer: The globe temperature, shown in figure (6), was measured by using the AZ8778 globe thermometer (75mm diameter) for the field surveys.
- The global radiation was measured by CM6B Pyranometer, shown in figure(7), that tracked global radiation, which is a combination of direct and diffused solar radiation and the solar radiation that was reflected from the surroundings.

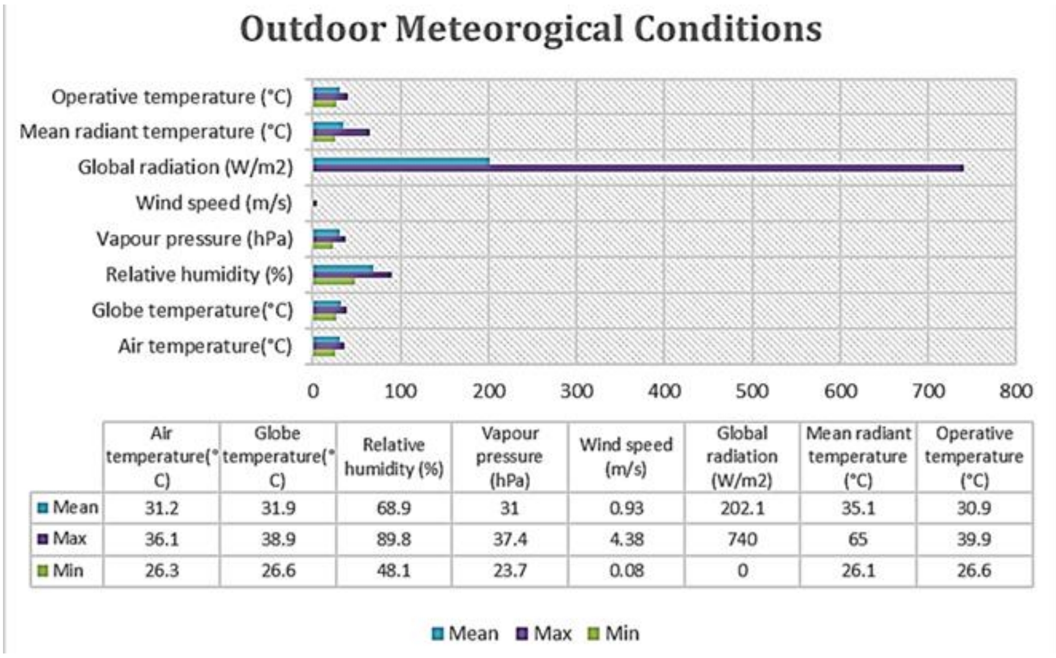
Fig. (5): LM-8102

Fig. (6): AZ8778 globe thermometer

Fig. (7): CM6B Pyranometer

2.4 Meteorogical Conditions

Outdoor microclimatic variables, which were measured during the survey in the study areas in BUE campus, are shown in Figure (8). It is cleared that air temperature and humidity were high, then the campus outdoor climate environment was hot and humid. Besides the values of wind speed was low and most of the wind speed values were less than 1.0 m/s.



	Air temperature(°C)	Globe temperature(°C)	Relative humidity (%)	Vapour pressure (hPa)	Wind speed (m/s)	Global radiation (W/m2)	Mean radiant temperature (°C)	Operative temperature (°C)
Mean	31.2	31.9	68.9	31	0.93	202.1	35.1	30.9
Max	36.1	38.9	89.8	37.4	4.38	740	65	39.9
Min	26.3	26.6	48.1	23.7	0.08	0	26.1	26.6

Figure (8): Gender distribution of the research samples in the survey

Analysis of subjective thermal responses

The data analysis was based on the whole data set (130 samples). Analysis has been conducted separately for morning period, mid-day period, and afternoon period, but the results have shown no much differences between different periods.

3.1 Thermal sensation and preference analysis

"Thermal sensation votes were based on the 7-point ASHRAE scale". No respondents voted for cold zone (TSV = -2, -3), in contrast to warm zone where most of the responses, 95 from total 130 respondents (73.1%) were at the warm zone (TSV>0) and 60% of the respondents who voted for the warm zone were females while 40 % were males. A ratio of 24.6% of respondents were neutral (TSV=0) 58% of them were females and 42% of them were males, the remaining responses (2.3%) voted for the cool side (TSV<0) 67% of them were males and 33% from them were females. Results are shown in Figure (9).

According to the field survey, the majority of respondents, 68% preferred cooler thermal environment, in contrast, very little respondents, 2% preferred warmer thermal environment, and the remaining 30% of the respondents preferred the same thermal environment with no change.

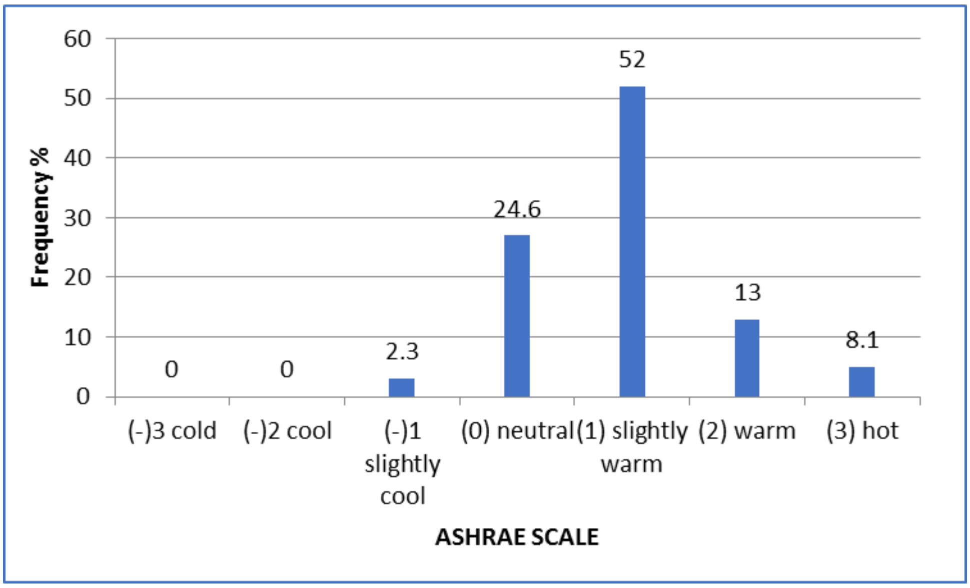


FIGURE (9): DISTRIBUTION OF THERMAL SENSATION VOTES

3.2 Wind speed sensation and preference analysis

"The wind speed scale ranges from stale (-2) to too much wind (+2)". The results show that the most of respondents (51 %) voted for (-1) little wind and (-2) stale in surrouding environment, but only 30% of the respondents considedred the wind speed was fine (0), and remaining respondents 19.0% felt that thermal environment was windy with scale (+1, +2). Results shown in Figure (10).

Therefore the pereference results indicates that most of respondents (55.4%) perfered more wind speed, but less respondents (11.6%) prefered less wind speed, and 35% of the respondents showed no need to change wind speed within their thermal environment.

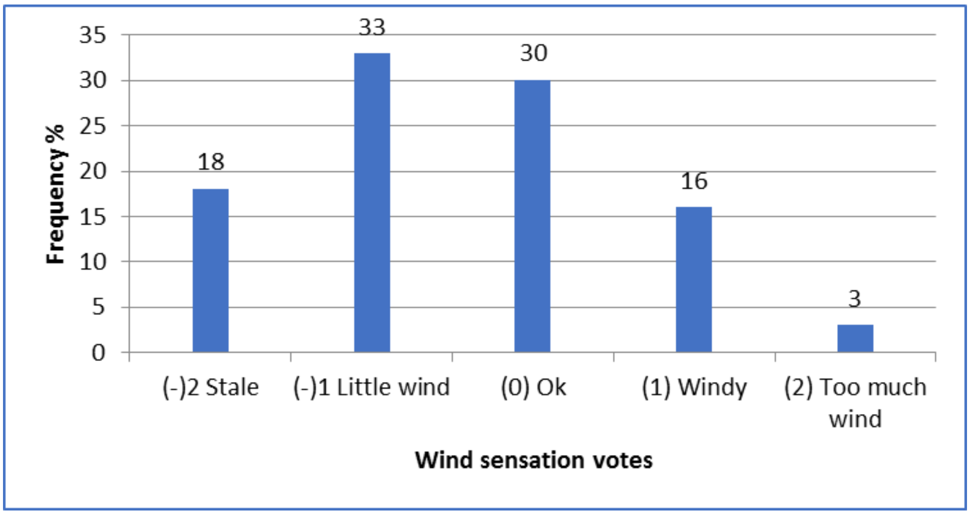


Figure (10): Distribution of wind sensation votes

3.3 Humidity sensation and preference analysis

"The scale ranges from too dry (-2) to "very humid (+2)". Half of the respondents (50%) have shown adaptation behavior with humidity as they voted for ok (0) in humidity scale. Whereas 37.7% of the respondents voted for (+1), (+2) humid and very humid respectivaly. The remaining respondents 12.3 % voted for (-1), (-2) dry and too dry respectivaly. Results shown in Figure (11).

According to the field survey in humidity preference results, the largest percentage (57.7%) of the respondents have adapted to humidity level at the surrounding environment and have not preferred to change humidity condition. Whereas 30.8% of the respondents voted for less humidity condition, the lowest percentage of respondents (11.5%) perferred more humidity.

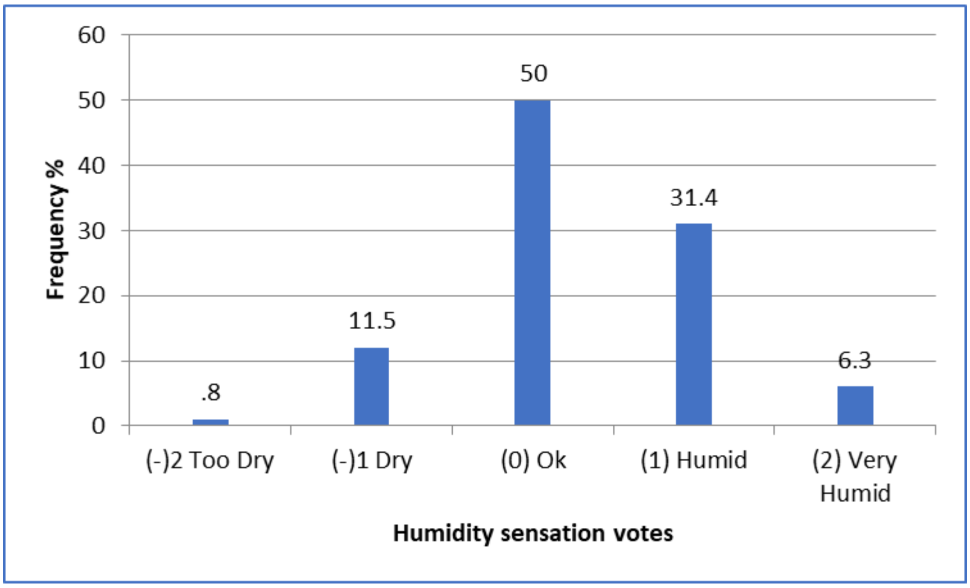


Figure (11): Distribution of humidity sensation votes

3.4 Sun sensation and preference analysis

"The sun sensation scale ranges from too weak (-2) to too strong (+2)". The results show that more than half of respondents (56.0%) felt that the sun is a little strong and too strong, (+1) and (+2) respectively. However, the lower percentage (6.0%) of the respondents considered the sun as a little weak and too weak, (-1) and (-2) respectively. Moreover, 38.0% of the respondents voted that the sun was fine (0). Results shown in Figure 12.

The sun preference results show 51.9% of respondents preferred no change, 46.9% of respondents indicated that they preferred it to be weaker and little respondents (1.2%) preferred the sun to be stronger.

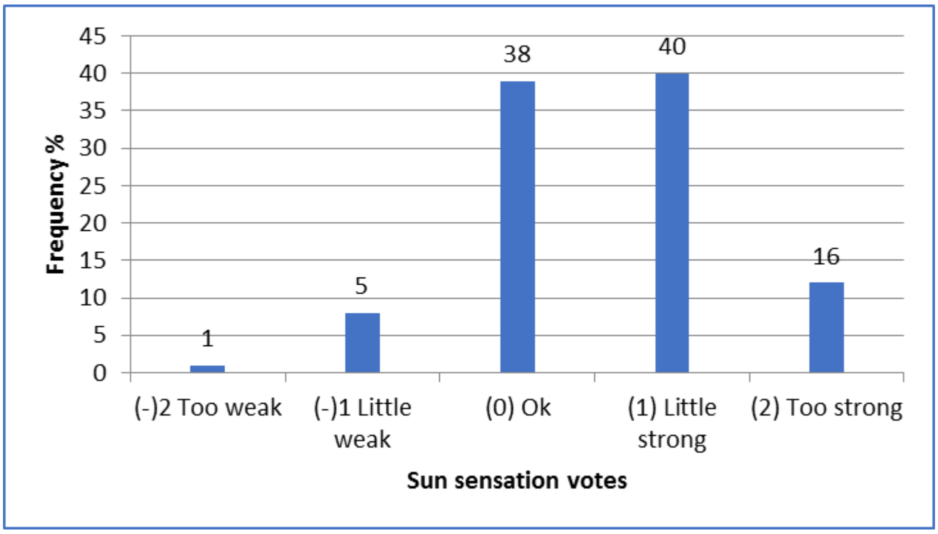


FIGURE (12): DISTRIBUTION OF SUN SENSATION VOTES

Thermal Sensation Vote in the Campus

Figure (13) shows the relationship between Physiological Equivalent Temperature (PET) and Thermal Sensation Vote (TSV) of BUE students.

"Based on latest studies of thermal comfort, "the questions on thermal sensation were asked on a seven-point ASHRAE scale (-3 cold, -2 cool, -1 slightly cool, 0 neutral, 1 slightly warm, 2 warm and 3 hot)".

Regression Equations:

Regression equations are used to determine the relationship between two or more variables that have cause- effect relation as well as to make more predictions (Gülden Kaya Uyanık, Neşe Güler, 2013).

The regression equation for BUE campus in Cairo, Egypt is:

MTSV=0.2461PET-6.5561

According to regression equation the neutral PET temperature was 26.6 °C by estimating (MSTV=0). In addition, results indicated that BUE campus respondents influenced obviously by PET temperature variation. It is due to, every 3.9 °C of PET one unit of thermal sensations have varied in BUE campus, Cairo, Egypt. The regression slope in BUE campus, Cairo, Egypt was 0.2461/ °C.

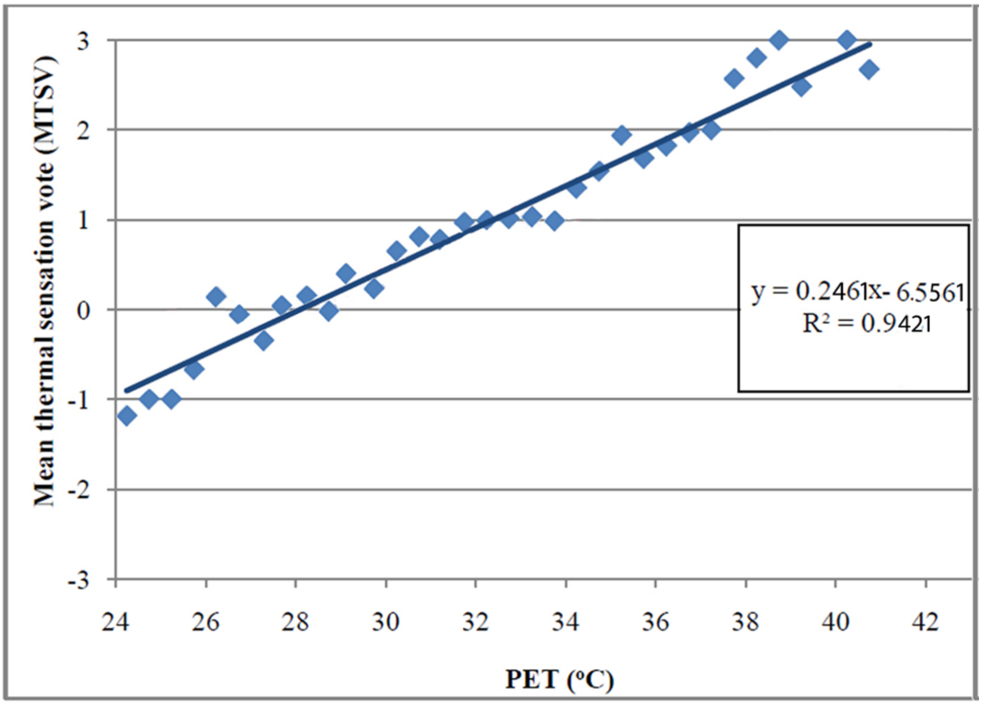


Figure (13): Regression of thermal sensation and PET

Results and conculsion

In hot arid climates, the results from the study that was performed at the BUE campus, Cairo-Egypt indicate that users in outdoor urban spaces may not be sensitive to the humidity changes; because of their adaptation with high humidity conditions. In the other side, users considered solar radiation so strong while taking in consideration that the filed surveys were conducted in the shaded areas, and mean value of wind speed was 0.93m/s, which shows that the results are correspondent with the low wind speeds observed in the field survey. Therefore, the shaded areas and different ventilation strategies should be improved in order to enhance the users experience in the outdoor space. Neutral PET temperature is 26.6 °C, BUE campus respondents were influenced obviously by PET temperature variation. It is due to, every 3.9 °C of PET one unit of thermal sensation have varied in BUE campus, Cairo- Egypt. Based on thermal sensation analysis and PET results of this study, it can contribute to enhance thermal comfort in campus urban spaces in hot arid contexts and to improve the quality of life in campus urban spaces. Concerning thermal comfort study scope, thermal adaptation is a challenging issue so it is important and recommended to determine suitable criteria for thermal adaptation area in the future and its effect on human thermal comfort.

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