Thermal Comfort Investigation of Pneumonia Patients in Non-centralized Airconditioned Wards in a Level 3 Hospital in the Philippines

Alvin Eber G. Arlanza, M Arch Program

Prof. Richard Martin E. Rinen / Prof. Cristopher Stonewall P. Espina

PROBLEM

This study examines the reliability and applicability of ASHRAE Standard 55 based on the predicted mean vote (PMV) developed by Fanger (1970) and the modified PMV of Lin and Deng (2008). There are still a limited number of studies that have investigated and validated Lin and Deng in field studies. Therefore, this research aims to clarify the thermal comfort perception of patients in a Philippine setting, validate the usability of Fanger's, Lin, and Deng thermal comfort models, and determine whether the comfort criteria of current hospital standards are applicable in a tropical setting.

The following are the specific objectives of the study;

- To evaluate the thermal sensation through field study based on subjective data.
- To evaluate and compare the predicted mean vote and modified predicted mean vote in the field study according to subjective and objective data collection.

METHODOLOGY

A field experiment was conducted in a level 3 teaching hospital in the Philippines. Twenty-nine (29) valid data sets have been collected from February to March of 2020. Thermal comfort is affected by environmental and personal parameters, which are measured simultaneously in patient rooms following research ethics protocol and health precautions.

Indoor air temperature, mean radiant temperature, air velocity, and relative humidity, along with metabolic rates and clothing insulation, were observed and recorded according to ASHRAE 55 and ISO 7730.

From the collated observed data, PMV, PPD, and other thermal indices were computed using the UC Berkeley Thermal Comfort Tool. The data were analyzed using linear and probit regression as well as measures of correlation tests (Kendall, Spearman, and Pearson Indexes) to assess the relationships or effects of variables on thermal satisfaction.

Figure 1. Instrument set-up during field study. Instruments were left to acclimatized for 10 minutes before recording. The sensors were located in-line with patient's head 1.0 meter above the floor.
(Photo by the author)

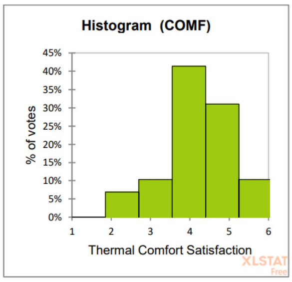
Monte Carlo Simulation was then used to test the results of linear regression. Random numbers were generated for TSV, PMV, and mPMV between their minimum, mean, and max values, then run to 1000 tests using the Simulation Master excel plug-in.

RESULTS

Respondent	Item	T_a (°C)	T_g (°C)	T_{ET} (°C)	T_{opt} (°C)	RH(%)	V_a (m/s)	I_{cl} (clo) ASHRAE 55	I_{cl} (clo) ISO7790	Activity (Met)
Patient (overall)	min	24.30	23.60	23.70	23.35	38.7	0.1	0.23	1.56	0.80
(N=29)	max	29.20	29.10	29.90	29.07	76.6	0.3	0.88	2.11	1.0
	mean	26.52	25.97	26.29	25.96	54.84	0.12	0.533	1.82	0.81
	SD	1.26	1.49	1.84	1.73	10.26	0.047	0.188	0.16	0.05

Figure 2. Descriptive Statistics of measured indoor environment and personal parameters.
(figure by the author)

The mean indoor air temperature and calculated operative temperature were both slightly higher than the DOH Technical Guidelines (25°C) and ASHRAE 55 (21-24 °C). The results show that the average T_a and T_{opt} in patient rooms are 26.5°C and 26°C, respectively.



Variable	Observations	Minimum	Maximum	Mean	S.D
COMF	29	2.000	6.000	4.276	1.032

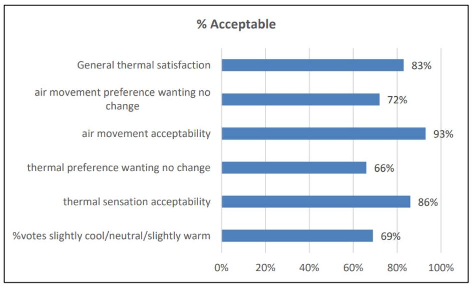


Figure 3. Thermal Environment Satisfaction and Thermal Preference
(figure by the author)

Above figure depicts patients' satisfaction (on a six-point scale) with their thermal comfort and ability to adapt when they feel too cold or too hot. If (1) is extremely dissatisfied, (2) is moderately dissatisfied, (3) is slightly dissatisfied, (4) is slightly satisfied, (5) is moderately satisfied, and (6) is extremely satisfied, the overall patient mean is 4.276.

The findings indicate that dissatisfaction is within the population's 20% threshold. In general, the environment was deemed acceptable by the patients in this study, rather than unacceptable.

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RESULTS (continuation)

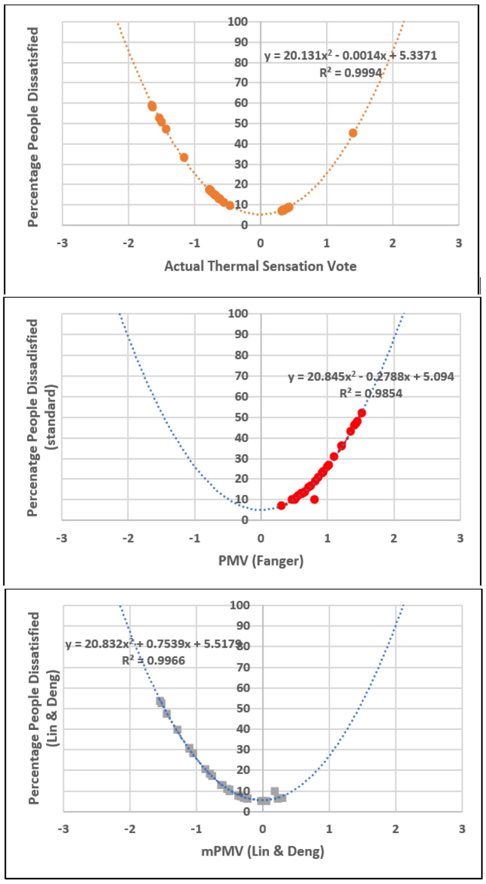

Figure 4. Comparison of bin Actual Thermal Sensation, Fanger's PMV and Lin and Deng's PMV vs their respective calculated PPD of all subjects observed in various patient's rooms

(figures by the author)

The above illustrates the distribution of thermal comfort conditions between cooler and warmer sensations as opposed to the standards set by ASHRAE. The PMV standards are only valid for healthy populations. When comparing PMV and patient TSV results, it was observed that the actual sensation from TSV is less than that of PMV and leans towards a much cooler thermal sensation. On the other hand, TSV results are slightly near the mPMV (Lin and Deng) calculated from the objective measurement. This suggests that the mPMV can be used as a close approximation of the TSV. This means the calculation method for PPD as a function of PMV for modified PMV by Lin and Deng can be used to predict the actual thermal sensation of the patient population based on these studies.

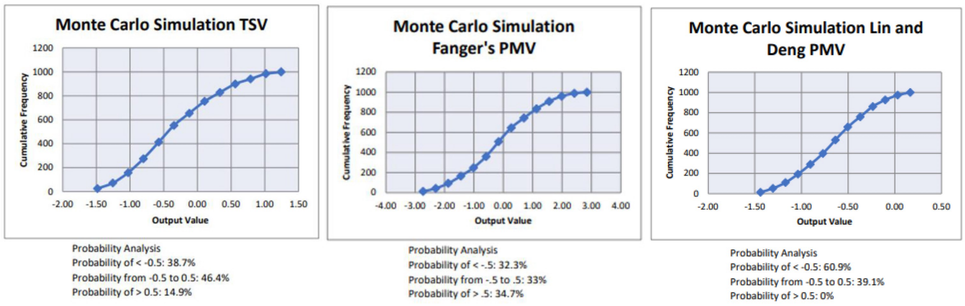

Figure 5. Monte Carlo Test Actual Thermal Sensation, Fanger's PMV and Lin and Deng's PMV

(figures by the author)

In order to validate small sample linear regression, random numbers were then generated derived from a probability function y=randomtriangulation (min, mean, max) of the TSV, PMV, and mPMV indices. One thousand iterations were then simulated. Figure 7.7.5, 7.7.6 and 7.7.7 indicate the probability of thermal comfort sensation within the range of (-0.5, 0.5) of the ASHRAE thermal comfort sensation at air temperature of 26.5 C, RH 55%, air velocity (0.12 m/s), clothing insulation (1.83 CLO), and metabolic rate (0.8 met) would be likely at 46.6% TSV, 33% Fanger's PMV, and 39% Lin and Deng's PMV.

This suggests that Fanger's PMV is overestimated and Lin and Deng's modifications of PMV are a better close approximation of the actual thermal sensation.

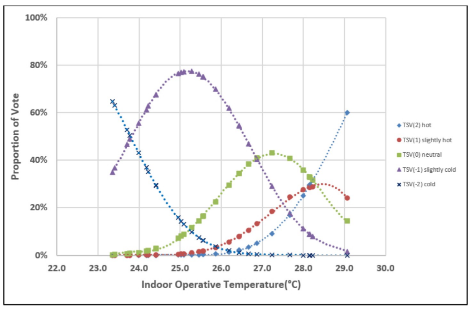

Figure 6. Proportion of actual thermal sensation

(figures by the author)

Examining the figure 6, thermal comfort satisfaction lies between the intersection of TSV (-1,0) and TSV (0,+1) at 23.8°C to 28.2°C. These findings indicate a narrower thermal comfort range and a neutral operative temperature of 27.2°C. These are above the prescribed thermal comfort range of ASHRAE 55 and DOH guidelines for design of hospital ward.

CONCLUSION

- Patients' preferred temperature is higher than neutral temperature, indicating that they expected a warmer thermal neutrality. The findings are consistent with those of previous field studies conducted in tropical hospital settings.
- The neutral operative temperature for patients was 25.8°C in a field study conducted between February and March of 2020. According to ASHRAE Standard 55-2010, the thermal comfort range based on the -1 to +1 of the seven-point ASHRAE 55 comfort scale which falls within the study's comfort range of 23.8 °C–28.8 °C. When compared to field studies conducted in Taiwan, Thailand, and Saudi Arabia, patients' thermal comfort satisfaction in the Philippines suggests a narrower range and +1.5 °C higher.
- Fanger's PMV is overly estimated as predictor of thermal comfort especially in frail populations

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