Investigation into the adaption of PMV to evaluation of the medical staff in hospitals in Guangzhou

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Abstract. In this investigation, the measurement thermal parameters and thermal comfort field survey were carried in six air conditioned hospitals in Guangzhou. A total of 114 valid questionnaires were collected. Based on the data, there were strong linear regression relationships between PMV and MTSV and operative temperature. The neutral PMV of medical staff was 0.004. The neutral operation temperature was 22.99 °C from the PMV model. The thermal comfort temperature which meets a satisfaction degree of 90% ranges from 21.29°C to 24.70°C. In addition, the neutral temperature was 24.36 °C from the linear regression of MTSV. The range of thermal comfort temperature was between 22.86°C and 25.85°C. Comparing the MTSV and PMV, the MTSV was lower than that of PMV.

Keywords. Medical staff; Predicted Mean Vote (PMV); Neutral temperature

1. Introduction
Thermal comfort mainly expresses people's subjective satisfaction with the thermal environment [1]. The World Health Organization points out that the thermal environment is closely related to people's health and productivity [2]. The comfortable thermal environment helps to improve staff efficiency. After decades of development of thermal comfort, researchers have studied the thermal comfort of indoors in shopping malls, offices, and residences. There are few studies on indoor thermal comfort in hospitals. The hospital is a complex place with different functional spaces, indoor facilities, large outpatient volume, strong mobility, and special occasions for patients, escort, and medical staff [3]. With the improvement of people's quality of life, the function of the hospital is no longer simply to satisfy the treatment of diseases, but also requires a comfortable and comfortable indoor environment. Creating a good hospital indoor environment to meet the psychological, physiological and social needs of patients has become the theme of modern hospital building interior environment design. The indoor environment includes: thermal environment, acoustic environment, and light environment. Creating a good indoor thermal environment is essential, and a comfortable thermal environment can help patients recover faster and improve the efficiency of medical staff. The difference between the medical staff and the patient and the accompanying care due to the difference in metabolic rate and thermal resistance of the garment causes different thermal sensations, and there is a difference in the thermal comfort environment of the demand. The medical staff work 8 hours per shift, and is in a mild working state during work. The metabolic rate is higher than that of the patient and escort. Whether the existing thermal comfort model is suitable for medical personnel in Guangzhou area has not yet been understood. Therefore, this paper mainly studies the adaptability of the thermal comfort evaluation model to medical staff in Guangzhou.

2. Research method
The location of the survey: the maternity department of the six hospitals in Guangzhou, doctor's clinic,
the nurse station, and the waiting room. The survey location is shown in Figure 1. For convenience, the number of the six hospitals is: H1, H2, H3, H4, H5, H6 (Hospital shortening: “H”). Research time: June 2018 to September 2018 during the summer. Subjects: Medical staff, 114 valid questionnaires were obtained through this survey. Subjective questionnaires include: personal information (height, weight, age, dress, etc.), thermal feeling voting value using ASHRAE level 7 indicators (3 heat, 2 warm, 1 slightly warm, 0 comfortable, -1 slightly cold, -2 cold, -3 cold), the expectation of a hot environment, the acceptance of a thermal environment, etc. Indoor environmental parameter test: air temperature, relative humidity, black ball temperature, indoor wind speed, test equipment using Beijing Tianjian Huayi thermal comfort recorder SSDZY-1 as shown in Figure 2, equipment parameters are shown in Table 1, field test photos as Figure 3-5 shows.

3. Analysis of survey results
3.1 Subject information, clothing thermal resistance and metabolic rate
The personal information of the medical staff is shown in Table 2. Clothing thermal resistance and metabolic rate are important parameters that affect the thermal comfort of the human body. During the
work of medical staff, the hospital requires uniform dressing. The summer suits for medical staff are divided into two types: thin long sleeves, casual pants, shoes, socks, and clothing thermal resistance of 0.46 clo; short sleeves, casual pants, shoes, socks, and clothing thermal resistance of 0.29 clo. The medical staff is in a mild labor state during work. According to the recommended value of ASHRAE 55-2017 metabolic rate, the medical staff of this article takes 1.4met.

| Table 2. Statistics of medical staff |
|-------------------------------------|
| Subjects | Max | Min | Mean | Variance |
| age | 50 | 20 | 32.65 | 8.37 |
| Height (cm) | 173 | 151 | 160.30 | 4.03 |
| Weight (kg) | 62 | 43 | 50.84 | 4.05 |

3.2 Indoor environmental parameters
The indoor environmental parameters were tested on-site from June 15, 2018 to August 16, 2018. The indoor parameter test results are shown in Table 3.

| Table 3. Indoor environmental parameters |
|----------------------------------------|
| Max | Min | Mean | Variance |
| Air temperature (°C) | 28.18 | 22.75 | 25.45 | 1.37 |
| Relative humidity | 97.20 | 75.55 | 85.03 | 4.68 |
| Average radiant temperature (°C) | 28.01 | 20.93 | 25.50 | 1.34 |
| Wind speed (m/s) | 0.54 | 0 | 0.11 | 0.12 |

3.2.1 Neutral temperature. In this paper, the Operative Temperature (Top) is selected as the evaluation index of the hospital thermal environment. This index comprehensively considers the radiation heat transfer and convective heat transfer between the human body and the surrounding environment, which is in line with the research requirements of this paper [4]. Respectively Mean Thermal Sensation Vote (MTSV), Predict Mean Vote (PMV) and Top Linear Regression were fitted, Obtain MTSV/PMV and Top regression fitting equation MTSV/PMV=a×Top+b, MTSV/PMV=0 obtain a thermal neutral value, MTSV/PMV=±0.5 or ±0.85 can obtain 90% or 80% of the acceptable temperature range for the subject. Four environmental parameters (air temperature, average radiant temperature, wind speed, relative humidity) and two individual parameters (clothing thermal resistance, metabolic rate) are entered in the CBE Thermal Comfort Tool (http://comfort.cbe.berkeley.edu/) Obtain the PMV value. The actual average thermal sensation of the medical staff MTSV fitting curve and the PMV predicted value fitting curve are shown in Fig. 6. According to the figure, the actual thermal sensation MTSV of the medical staff is deviated from the predicted value of PMV, showing the phenomenon of “scissors difference”. The MTSV and Top regression fitting equations are: MTSV=0.3212Top-7.8326 (R²=0.7621, P=0.873, sig.=0.01) ; The results show that MTSV and Top are significant, the correlation coefficient between MTSV and Top is 0.7621, MTSV=0 obtains the actual thermal neutral value of medical staff at 24.39 °C, MTSV ± 0.5 or ± 0.85 to obtain 90% or 80% of the acceptable range of medical personnel is 22.83~25.94 °C, 21.74~27.03 °C. The PMV and Top regression fitting equations are: PMV=0.2856Top-6.7828 (R²=0.9275, P=0.963, sig.=0.00) ; The results show that PMV and Top are significant, the correlation coefficient between PMV and Top is 0.9275, PMV=0 obtains the actual thermal neutral value of medical staff at 23.75 °C, PMV ± 0.5 or ± 0.85 to obtain 90% or 80% of the medical staff acceptable range of 22.00 ~ 25.50 °C, 20.77 ~ 26.73 °C. Comparing the MTSV model with the PMV results, the actual thermal neutral temperature of the medical staff is higher than the predicted thermal neutral temperature, indicating that the predicted value of the PMV model underestimates the ability of the medical staff to withstand the thermal environment; The slope of the regression fitting curve indicates the sensitivity of the medical staff to the thermal environment. The slope of the MTSV model is greater than the slope of the PMV model, and the actual thermal sensation of the medical staff is more sensitive to Top. The actual range of actual acceptable temperature for 90%
or 80% of health care providers is narrower than the predicted range.

![MTSV/PMV and Top regression fitting curve](image)

**Figure 6.** MTSV/PMV and Top regression fitting curve

| Neutral value (°C) | 90% acceptable range (°C) | 80% acceptable range (°C) |
|-------------------|---------------------------|--------------------------|
| MTSV=0.3212Top-7.8326 | 24.39 | 22.83–25.94 (52.78%) | 21.74–27.03 (88.89%) |
| PMV=0.2856Top-6.7828 | 23.75 | 22.00–25.50 (45.61%) | 20.77–26.73 (78.07%) |

**Table 4.** 90% or 80% medical staff acceptable range

3.2.2 Preference temperature. In this paper, the subjective questionnaire sets "the expectation of the subject's thermal environment: increase (+1) and decrease (-1)". The medical staff voted that the temperature "has been higher (+1)" accounted for 15.79%, and the expected temperature "reduced (-1)" accounted for 38.60%. The preference Top was obtained by Probit regression analysis curve intersection point was 24.43 °C. The preference Top is 0.04 °C higher than the actual thermal neutral temperature, and the preference Top is 0.68 °C higher than the predicted thermal neutral temperature.

![Medical staff “TPV=1” and “TPV=-1” probit curves](image)

**Figure 7.** Medical staff “TPV=1” and “TPV=-1” probit curves
3.2.3 Actual percentage dissatisfaction. In this paper, the subjective questionnaire sets the “Whether you are acceptable to the hot environment: acceptable (0), unacceptable (1)”. The acceptable rate of medical staff to the thermal environment was 70.18%, and the unacceptable rate was 29.82%. The Actual Percentage Dissatisfaction (APD) and Top polynomial regression fit curve is shown in Figure 8. Multiple regression fitting equation APD = 0.0434Top2 - 2.058Top + 24.483, APD = ± 0.5 or ± 0.85 to obtain 90% or 80% of the medical staff acceptable comfort temperature upper limit of 24.71 °C, 25.53 °C. The acceptable upper temperature limit for 90% or 80% of medical personnel obtained by MTSV/PMV = ±0.5 or ±0.85 is higher than the 90% or 80% acceptable temperature upper limit obtained by APD = ±0.5 or ±0.85.

![Figure 8. APD and Top fitting curve](image)

3.2.4 Compared with previous research results. A summary of the research on the thermal comfort of medical staff by domestic and foreign scholars is shown in Table 5 below. It is known from Table 5 that the actual thermal neutral value of health medical staff in Guangzhou obtained by MTSV = 0 is 1.11 °C lower than the actual thermal neutral value obtained in Thailand. The predicted thermal neutral value of health medical staff in Guangzhou obtained by PMV = 0 was 1.35 °C higher than the predicted thermal neutral value obtained in Thailand. The actual thermal neutral value of summer medical staff in Guangzhou obtained by MTSV = 0 is 2.59 °C higher than the actual thermal neutral value obtained in winter in the Netherlands. The upper limit of acceptable temperature for 80% of medical staff in Guangzhou obtained in this paper is higher than the upper limit of 80% acceptable for medical staff in Thailand and the Netherlands. The main reason for the differences between the results of the medical staff in this paper and Thailand and the Netherlands may be due to differences in climate or physical conditions. Guangzhou belongs to the south subtropical monsoon climate, and Thailand belongs to the tropical monsoon climate. The climate features: high rainfall and high temperature. People have long-term living in high temperature and high humidity environment and have strong adaptability. Therefore, the obtained thermal neutral values are not much different. The Netherlands is a typical temperate marine climate with sufficient precipitation throughout the year, suitable temperatures, and warm winters and cool summers. Therefore, the winter medical care neutral value obtained is low.
Table 5. Summary of research on thermal comfort of medical staff at home and abroad

| Scholar          | Location   | Regression fitting equation | Neutral value (°C) | Preference value (°C) | 90% acceptable range (°C) | 80% acceptable range (°C) |
|------------------|------------|----------------------------|--------------------|-----------------------|---------------------------|---------------------------|
| Present paper    | Guangzhou | MTSV=0.3212Top-7.8326       | 24.39              | 22.83−25.94           | 21.74−27.03               |
|                  |            | PMV=0.2856Top-6.7828        | 23.75              | 22.00−25.50           | 20.77−26.73               |
| Sutida et al.    | Thailand   | PMV=0.4316Top-11.011        | 22.4               | 22.00−25.60           | 20.77−25.53               |
|                  |            | ASV=0.2177Top-4.8862        | 25.5               |                       |                           |
| Derks et al.     | Netherlands| TSV=0.68Ta-14.81            | 21.8               |                       | 20.3−23.3                 |

A: 90% or 80% acceptable range based on MTSV = ±0.5 or 0.85
B: 90% or 80% acceptable range based on PMV = ±0.5 or 0.85
C: 90% or 80% acceptable range based on APD = ±0.5 or 0.85
D: thermal comfort range based on TSV = ±1
E: summer
F: winter

4. Conclusion
This paper has obtained the following conclusions through the analysis of the thermal comfort of medical staff in 6 hospitals in Guangzhou:

1) The actual thermal neutral value of the medical staff in summer is different from the predicted neutral value. The actual thermal neutral value is 24.39 °C, and the predicted neutral value is 23.75 °C. Through the Probit regression curve analysis, the expected value of medical staff was 24.43 °C. The expected value is higher than the actual thermal neutral value and the predicted thermal neutral value.

2) The actual 90% or 80% medical staff acceptable range is 22.83−25.94 °C, 21.74−27.03 °C, and the predicted actual 90% or 80% medical staff acceptable range is 22.00−25.50 °C, 20.77−26.73 °C. The upper limit of acceptable temperature for 90% or 80% of medical personnel obtained through the actual dissatisfaction rate APD is 24.71 °C, 25.53 °C.

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