Importance of Thermal Comfort in Hospitals- A Review

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Abstract - This paper reviews the thermal comfort aspect in hospital buildings. There are many advantages of having a proper thermal environment in hospitals, and it helps in the healing of the patient. Researchers have studied thermal comfort through the survey as well as through experimentation. In recent years the focus is shifted towards the passive cooling aspects because of the high energy consumption of HVAC devices.

Keywords: Thermal Comfort, Computational Fluid Dynamics, Hospital

I. INTRODUCTION

The concept of thermal comfort is essential for human life and activities. In addition to thermal comfort, various points are also considered such as visual comfort, acoustic comfort, protection against radiation and air quality to ensure the appropriate class and sustainability of the living environment [1,2].

Thermal comfort also includes psychological and physiological aspects, in addition to the ambient parameters [3,4]. The effect of thermal comfort in human activities is being considered extensively in all aspects of life such as energy management, energy efficiency, and environmental impact.

Several studies have been done to establish standards in thermal comfort for occupants in hospitals. Part of these researches has been done in thermal comfort for hospital occupants, including patients and hospital personnel. Infections influence indoor air quality, and it affects the healing process of patients. Hygiene and safety are the main parameters to establish codes and standards for hospitals currently, but the concept of thermal comfort as a part of patients' healing process is yet to analyzed in more detail.[5]

There are many differences in Air- Conditioning of hospital and any other building. In the hospital, the air movement is restricted in and between the various departments. Also, there are specific requirements for ventilation and filtration to dilute and remove contamination. The temperature and humidity requirements are too different for each section. Since the thermal comfort in hospitals affects the healing process of the patient, so more sophistication in design is needed to permit accurate control of environmental conditions. Hence thermal comfort in hospitals depends upon control of temperature, humidity, and air movement.

In this paper, the thermal comfort requirement of the hospital is discussed. The area of thermal comfort is vast, but we will review the various methods of achieving thermal comforts in the hospital and also the use of computational fluid dynamics to model the hospital or a particular ward.

Nomenclature and Abbreviations

PMV- Predicted Mean Vote

AMV-Actual Mean Vote

ASHRAE- American Society of Heating, Refrigerating and Air-Conditioning Engineers

PPD-predicted percentage of dissatisfied

ISO-International Organization for Standardization

II. THERMAL COMFORT IN HOSPITALS

People's living standard has improved with the advancement of the global economy in recent years, and demands for medical treatment have increased multiple times, which will push forward the demand for the construction of medical facilities. Therefore, clean operation room and hospital wards will play an important role. We know that the cleanness of a hospital is a crucial link in controlling infection, which will directly influence the infection rate. Therefore, the requirement for clean air conditioning technology is gradually increasing [6].

There is much research about thermal comforts in hospitals. Some studies focuses on the environmental parameters such as indoor temperature, humidity, and air movement; some other focuses on thermal discomfort and the thermal sensation of patients and hospital staff.

The first part of studies undertaken in hospitals concentrates on the influence of indoor air quality on the hygiene of these environments. For example, although, ASHRAE presents chapter eight of its Applications Handbook regarding the healthcare facilities, thermal comfort concept seems to have been ignored within this publication as an essential subject. According to chapter Eight (healthcare facilities) of the ASHRAE Applications Handbook [7], temperature and humidity can inhibit or

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increase the growth of bacteria, and activate or deactivate viruses.

A thermal comfort study conducted in Belgium [8], on 99 patients with different types of illness, showed that there was no notable difference between PMV and AMV for all the different wards except for neurology. In [9], 927 sets of data were collected in a university hospital in Taiwan to show that physical strength had a highly significant effect on thermal sensation, but gender, age, and acclimatization had not. A field study [10] on thermal comfort carried out in Malaysia revealed that the neutral temperature in the daytime around 26◦C, comfort range is between 25◦C and 27.7◦C, and the acceptable range will be 23.8◦C to 29◦C.

In[11], the authors indicated that people with certain chronic medical conditions are more susceptible to heat, such as cardiovascular and cerebrovascular diseases, diabetes, respiratory and renal diseases, Parkinson's disease, Alzheimer's disease, and epilepsy. [12] established that patients expect a warmer indoor environment than neutrality.

Kameel et al. in their study have explained that relative humidity and air temperature can inhibit or promote the growth of bacteria and viruses. So the temperature and humidity should be in a particular range as specified, to control infection and provide thermal comfort. [13] They also concluded that low humidity could increase susceptibility to respiratory disease as well as affect comfort.

High temperature may cause increased outgassing of toxins from building materials, and low temperature can cause occupant discomfort including shivering, inattentiveness and muscular and joint tension. Relative humidity affects occupant comfort both directly and indirectly. Low humidity affects comfort and health in ways such as drying nose, throat, eyes, and skin. Thermal sensation is an indicator of overall thermal comfort and acceptability at lower levels of humidity. However, referred to a study done by Tanabe et al. in high humidity levels, thermal sensation alone is not a reliable predictor [14].

Nomura et al. have observed that to satisfy patient comfort, the total air changes per hour must be a minimum of 6 ACH, but in rooms with supplemental heating and cooling this rate may be reduced to 4 ACH [15].

There are other researches which compare the thermal comfort conditions required by patients in hospitals, with regular occupants of other buildings. In these researches, the variations in physical and mental conditions of patients are compared with healthy people. These types of studies generally use the questionnaire and monitoring methods to compare the desired thermal comfort conditions.

Mazzacane et al. concluded that it is difficult to realize the thermal conditions recommended by ISPESL guidelines for all staff in the operating room because of the level of activity is different during the surgery for different staff, and according to the different kinds of surgery. [16,17]

Balaras et al. have indicated that the advisable indoor air temperature is 20–24 ◦C according to standards, but the use of lower or higher temperature is acceptable when patient comfort and medical conditions require those conditions. They also noted that higher indoor air temperatures might cause discomfort, as well as, the more favorable growing conditions for bacteria or their migration from and to the patient [18].

Mora et al. have reported a radiant asymmetry ranging from 6 ◦C to 7 ◦C over the operating table, and from 10 ◦C to 12 ◦C over the floor level (at the height of 1.1 m), because of thermal radiation emitted from surgical lights, regardless of the indoor air temperature [19]

Hwang et al. have observed that Only 40% of all measured thermal environments were within the ASHRAE recommended comfort zone in Taiwan[20]. Skoog et al. concluded that reducing the air relative humidity increases respiratory problems [21]. Hashiguchi et al. found that the average recorded relative humidity (less than 40%) in sickrooms of Japan, reached levels known to promote the spread of influenza viruses [22]. Melhado et al. concluded that the layout of the operating room has a little influence on thermal comfort.[23]. Leslie et al. found that temperature above 23 ◦C is usually intolerable for the surgical Staff [24]. Fossum et al. observed that the memories of thermal comfort or discomfort during surgery affect a patient's overall satisfaction with surgical care[25]. Johnston et al. concluded that to prevent patient thermal risk; the temperature must not drop below 21 ◦C[26]

Some authors discussed the thermal comfort aspect of not only the patients but also the staff of the hospital. In [27], the authors studied the thermal comfort of 114 medical staff in hospitals in Malaysia and found that the neutral temperature was 26.4◦C. The comfort temperature range that satisfied 90% of the occupants in the space was 25.3◦C to 28.2◦C. A field survey conducted in Japan and based on 36 patients and 45 staff members [28] showed that 64.5% of staff felt"warm", "hot" or "very hot" with relatively low temperature (20–23◦C)and low humidity (less than 40%)which is much higher than that of patients which were only 22.3%. Thus, health-care staff experience more warmth than patients. [29] studied the thermal comfort of patients and staff in four Iranian hospitals. It showed that, with air temperature from 20◦C to 28◦C, air velocity from 0.1 m/s to 0.5 m/s, and relative humidity from 30% to 60%, the hospital staff generally experience uncomfortably hot thermal conditions.

Murphy et al. has suggested guidelines for indoor temperature, humidity and air-change requirements for operation and surgery rooms, and has noted that the surgeon expects a lower room temperature than those stated in these guidelines [30]. The major problem as he has found

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in his study is the need for lower air temperature, the high relative humidity and the condensation risk in surgery rooms. Murphy has concluded that if the design is based solely on temperature, then it will not be able to meet the requirements, especially at the lower temperature.

III. CONCLUSION

To maintain thermal comfort in hospitals, various passive cooling techniques can be used, and it reduces the temperature significantly in some areas. Computational fluid dynamics is found useful in finding the thermal comfort index such as PMV and PPD and helps in determining the better passive cooling techniques to be used as per the requirement.

REFERENCES

[1] RJ de Dear, Akimoto T, Arens EA, Brager G, Candido C, Cheong KWD, Li B, Nishihara N, Sekhar SC, Tanabe S, Toftum J, Zhang H, Zhu Y. Progress in thermal comfort research over the last twenty years. Indoor Air 2013;23:442–61.

[2] Alfano FRA, Olesen BW, Palella BI, Riccio G. Thermal comfort: design and assessment for energy saving. Energy Build 2014;81:326–36.

[3] Parsons KC. Environmental ergonomics: a review of principles, methods and models. Appl Ergon 2000;31:581–94.

[4] Liu J, Yao R, McCloy R. A method to weight three categories of adaptive thermal comfort. Energy Build 2012;47:312–20.

[5] Jamal K, Nazanin N, Thermal comfort in hospitals – A literature review. Renewable and Sustainable Energy Reviews 16 (2012) 4071– 4077

[6] J M. Shen. Concept and feature of China code for clean operating room, J. Contamination Control and Air-conditioning Technology. S1(2006) 1-6.

[7] ASHRAE. Chapter Eight: healthcare facilities. In: HVAC Applications handbook. ASHRAE; 2015.

[8] J. Verheyen, N. Theys, L. Allonsius, F. Descamps, Thermal comfort of patients:objective and subjective measurements in patient rooms of a Belgian healthcare facility, Build. Environ. 46 (May (5)) (2011) 1195–1204.

[9] R.-L. Hwang, T.-P. Lin, M.-J. Cheng, J.-H. Chien, Patient thermal comfort requirement for hospital environments in Taiwan, Build. Environ. 42 (August(8)) (2007) 2980–2987.

[10] F. Azizpour, S. Moghimi, E. Salleh, S. Mat, C.H. Lim, K. Sopian, Thermal comfort assessment of large-scale hospitals in tropical climates: a case study of University Kebangsaan Malaysia Medical Centre (UKMMC), Energy Build.September (64 (2013) 317–322.

[11] D. Ormandy, V. Ezratty, Health and thermal comfort: from WHO guidance to housing strategies, Energy Policy October (49 (2012) 116–121.

[12] J. Khodakarami, N. Nasrollahi, Thermal comfort in hospitals – a literature review, Renew. Sustain. Energy Rev. 16 (August (6)) (2012) 4071–4077.

[13] Kameel R, Khalil E. Thermal comfort VS air quality in air-conditioned healthcare applications. In: 36th AIAA thermophysics conference 2003. 2003

[14] Tanabe S, Kimura K, Hara T. Thermal comfort requirement during summer season in Japan. ASHRAE Transactions 1987;93(1):564–77.

[15] Ninomura PE, Bartley J. New ventilation guidelines for health-care facilities. ASHRAE Journal 2001:29–33. Ventilation, June.

[16] Mazzacane S, Giaconia C, Costanzo S, Cusumano A. A survey on thermal conditions experienced by a surgical team. Indoor and Built Environment 2007;16(2):99–109.

[17] ISPESL (Istituto Superiore Prevenzione e Sicurezza sul Lavoro) Guidelines: Dipartimento di Igiene del Lavoro Linee guida per la definizione degli standard si sicurezza e di igiene ambientale dei reparti opratori: [Department of Occupational Hygiene, Guidelines defining safety standards and environmental hygiene for surgical departments], 1999.

[18] Balaras CA, Dascalaki E, Gaglia A. HVAC and indoor thermal comfort conditions in hospital operating rooms. Energy and Building 2007;39:454–70.

[19] Mora R, English MJM, Athienitis AK. Assessment of thermal comfort during surgical operations. ASHRAE Transactions 2001;107(part 1):52–62.

[20] Hwang RL, Lin TP, Cheng MJ, Chien JH. Patient thermal comfort requirement for hospital environments in Taiwan. Building and Environment 2007;42: 2980–7.

[21] Skoog J. Relative air humidity in hospital wards – user perception and technical consequences. Indoor and Built Environment 2006;15(1):93–7.

[22] Hashiguchi N, Hirakawa M, Tochihara Y, Kaji Y, Karaki C. Thermal environment and subjective responses of patients and staff in a hospital during the winter. Journal of Physiological Anthropology and Applied Human Science 2005;24(1):111–5.

[23] Melhado MA, Beyer PO, Hensen JM, Siqueira LFG. The thermal comfort, the indoor environment control, and the energy consumption in three types of operating rooms. In: Building simulation, 9th International IBPSA Conference.2005.

[24] Leslie K, Sessler DI. Perioperative hypothermia in the high-risk surgical patient. Best Practice & Research: Clinical Anaesthesiology 2003;17(4):485–98.

[25] Fossum S, Hays J, Henson MM. A comparison study on the effects of prewarming patients in the outpatient surgery setting. Journal of PeriAnesthesia Nursing 2001;17:102–14.

[26] Johnston IDA, Hunter AR. The design and utilization of operating theatres. The Royal College of Surgeons of England; 1984.

[27] Y.H. Yau, B.T. Chew, Thermal comfort study of hospital workers in Malaysia,Indoor Air 19 (December (6)) (2009) 500–510.

[28] N. Hashiguchi, M. Hirakawa, Y. Tochihara, Y. Kaji, C. Karaki, Thermal environment and subjective responses of patients and staff in a hospital during winter, J. Physiol. Anthropol. Appl. Hum. Sci. 24 (January (1)) (2005)111–115.

[29] J. Khodakarami, I.P. Knight, Measured thermal comfort conditions in Iranian hospitals for patients and staff, in: Proc. of Clima 2007 WellBeing Indoors,Helsinki, Finland, June, 2007, pp. 1–7.

[30] Murphy J. Temperature and humidity control in surgery rooms. ASHRAE Journal 2006;48:18–25. Health-Care HVAC.

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