Evaluation of thermal comfort levels concerning the spatial arrangement in an operating room

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Abstract
A person's thermal sensation is influenced by his physical activity and clothing, as well as by environmental parameters, such as air temperature, mean radiant temperature, relative air velocity and relative humidity of the air. The aim of this study regards the evaluation of thermal comfort levels experienced by the surgical staff at operating rooms. The methodology in this study was based on a survey on thermal sensation of the surgical staff using questionnaires. The assessment of the subjective thermal sensation in the operating room was provided by a total of 71 questionnaires. The results show an over-estimation of thermal sensation using the PMV (Predicted Mean Vote) calculation, as well as differences between regions on the studied operating room.

Keywords: thermal comfort, operating rooms, PMV index, subjective evaluation.

Presentation Preference: Oral

1. INTRODUCTION
People's thermal comfort is defined as the condition of mind which expresses satisfaction with the thermal environment. This condition is not only a health subject, but also a productive issue. In fact, at temperatures from 25°C to 32°C, the human productivity decreases as the temperature raises (d'Ambrosio Alfano, Palella, & Riccio, 2011). Concerning these points, comfort evaluation is a subject of major importance nowadays, as health has become increasingly valued. There are several measures that can create a comfortable environment, like a proper design of equipment and installations, providing proper air conditioning and a correct clothing selection (Parsons, 2002). The study of the thermal comfort levels at healthcare facilities has been a focus of research. The design of a heating, ventilating, and air-conditioning (HVAC) system for an operating room is aimed to prevent the risk of infections during surgical operations while maintaining an adequate comfort condition for the patient and the surgical staff. Proper indoor comfort condition and indoor air quality are prerequisites for securing a safe and suitable environment for an operating room (Van Gaever, Jacobs, Diltoer, Peeters, & Vanlanduit, 2014). These systems ensure air exchanges, pressurisation, temperature control, and air humidity, being of utmost importance in healthcare facilities. Comfort evaluation give us not only information about how people are feeling, but also whether the HVAC systems are working effectively or need to be adjusted, in order to provide a more effective comfort situation. People's sensation of thermal comfort can be evaluated by a standard index: the Predicted Mean Vote (PMV), based on the work of P.O. Fanger. This PMV index assesses a person's thermal sensation on a 7 point scale ranking, varying from -3 (cold) to +3 (hot) with the value 0 indicating neutral thermal sensation. Thermal comfort is established between -0.5 and +0.5 (ISO 7730:2005).
In this work, the thermal comfort variables were measured for the PMV calculation for all the surgical staff members taking into account their location in the operating room. The Actual Mean Vote (AMV), which is the subjective assessment of the thermal environment, was also calculated through questionnaires, in order to complement the present study. The correspondent sample was constituted by 71 health professionals.

2. MATERIALS AND METHOD
Thermal comfort depends both on the thermal parameters, air temperature, air velocity, radiant temperature, relative humidity, as well as on individual parameters such as metabolism and clothing insulation. Therefore, to correctly evaluate thermal comfort, it is necessary to obtain all the parameters. The clothing insulation was obtained through a survey were it was stated the different clothing used by each individual. The metabolism rate was obtained through observation, which is a method indicated on ISO 8996:2004. The resulting metabolism is a time weighted average of the different workloads for each considered profession. Regarding the environmental parameters, they were obtained using an indoor climate analyser, Brüel & Kjær, type 1213. This device has a platinum transducer (Pt100) for the air temperature measurement, as well as for the radiant symmetry. However, the last transducer has a different configuration to measure the radiant temperature. For the air velocity temperature the device uses an anemometer transducer. The humidity values on the other side were measured with an USB Temperature/Humidity Data Logger. Concerning the room displacement, two different regions were considered and evaluated using five measurement points. One point was located the closest possible of the centre (regarding the patient safety) and defined as region 2, the remaining data were taken around the region 1 for a better sampling. Region 2 accounts for the ventilation laminar flow, the chirurgical lamps, and the staff with more metabolic activity. On the other side, Region 1 has lower velocities, is out of the chirurgical lamps' range, and the staff has a lower metabolic activity (see Figure 1).
For each measurement it was given the necessary time for the equipment stabilization, never less than five minutes. The questionnaires where applied after the chirurgical staff ended their activities, where it was answered their thermal

sensation before, during and after the operation among other data considered relevant for the study. Considering the staff metabolic activity, four groups were chosen: surgeon, assistant surgeon, instrument nurse and other personal.

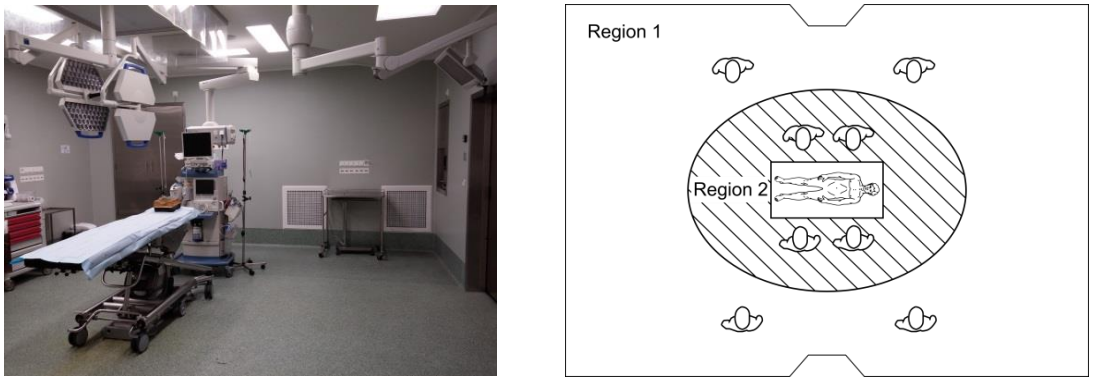

Figure 1 – Representation of the operating room. The real image is to the left and the schematic image is to the right.

3. RESULTS AND DISCUSSION

After the conclusion of measurements and questionnaires, all data were treated. The first step was to convert the observed activity into values of metabolic rate for each considered activity. The data showed that the most significant difference of metabolism was between the surgeon and the users of Region 1, with a metabolism of 129 W and 104 W respectively. The other major difference between these two regions was the radiant temperature, which was calculated taking into account the area factor of a human body. The average temperature increase relatively to the ambient temperature in Region 2 was 1.6 ºC, contrasting with an average increase of 0.6 ºC in Region 1. Adding to these results, one should also keep in mind that the measurements could not take place in the exact position of the professional's workplace. In this sense, the increase of radiant temperature for the Region 1 users could be even more significant.

Having the preliminary data treated 36 results were kept. In order to increase the effectiveness in the data treatment, it was created a Python script, according with the algorithm published on ISO 7730:2005 which is able to read all the data and calculate the PMV values. With this information, one can now compare the thermal comfort prediction with the values that the operating room users felt, answered in the questionnaires. The results are represented in Figure 2.

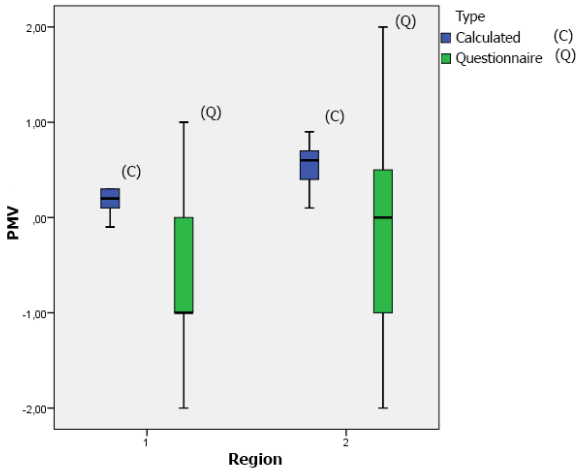

Figure 2 – Box plot for the PMV distribution according to the region. The group (C) represents the calculated values, and group (Q) represents the values from the questionnaires.

The most notorious property is the distribution. Observing Figure 2, one can easily notice that although the calculated data predicted a small array of answers, since the PMV variables didn't change much between cases, in what concerns the actual vote for the thermal sensation, people answered with greater disparity than expected. This result can be explained by peoples' individuality. Despite thermal neutrality, people can feel thermally comfortable at different situations, as thermal comfort is the condition of mind that expresses satisfaction with the thermal environment (ASHRAE Standard 55, 2004). Besides, the calculated metabolic rate can present a considerable error in the study. This is explained by the fact that every person's body is a particular one and that even if the activity it develops is the same, it may exist a greater or smaller effort to accomplish the given task. This originates different metabolic rates that differ from the average values described in ISO 8996:2004.

In addition to the distribution, it should also be discussed the median and the data concentration. The most visible point between the median of the calculated values and the responded on the questionnaires is that the calculated data showed

a tendency to positive PMV values, this is, towards the hot sensation. However, in both regions for the questionnaires' results, there is a tendency to negative values with more than 50% of the cases below the value of thermal neutrality. This effect is even more evident in Region 1, where 50% of the inquired responded between the values of -1 (slightly cool) and -2 (cool) for the PMV scale, which indicates dominancy towards a cold sensation inside this region. This cold tendency in Region 1 is expected when compared to Region 2, since the last is more exigent in terms of metabolism and also has a greater radiant temperature due to the chirurgical lamps. However, the data of the questionnaires in Region 2 do not show a tendency towards the cold or the hot region.

4. CONCLUSIONS

In the present work, one can verify that the calculated PMV overestimates the thermal sensation for the population in study and is not a good approximation for the real sensation. Besides, the inquired people are not so consensual in their opinion of thermal comfort, showing the dominance of the individual factors and personal preferences. Other important point is that independently of the data source, people working on Region 1 are more susceptible to feel cold than people on Region 2. Fact that is more preponderant in the questionnaires' data.

Further improvements related to the present work will take into account different environmental conditions, as these study was mostly carried in spring. This becomes relevant as the health professionals do not make any previous stabilization of their temperature before entering the chirurgical rooms. Keeping in mind the future of the investigation, the shown data will be subjected to statistical tests that correlate the differences between the calculated and subjective data.

6. REFERENCES

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