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Survey-based study on sportsmen performance under different air parameters in sport halls

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Abstract
Nowadays an importance of indoor air quality is highlighted by numerous researches. There are strong dependence between CO2 concentration and human health and office workers performance. This study provides research on sportsmen performance under different indoor air parameters. During the study the IAQ parameters were measured in three different sport halls and special questionnaires were distributed between taekwondo sportsmen. Age of sportsmen 10 – 15 years. In order to evaluate performance of taekwondo fighters the total number of received scores by the same fighters in different sport halls were compared. Results have shown that in sport hall with higher CO2 concentration number of received scores were much smaller in comparison to halls with CO2 concentration at 1000ppm.

Keywords - Ventilation; CO2 concentration; Sport halls; Indoor Air Quality, Energy Efficency.

1. Introduction

One of the most commonly used indicator of the indoor air quality is a concentration of CO2. The advantage of this method is that it is relatively easy to do measurements and that it is not expensive. Also, many studies and practical experience have shown that this method is reliable and accurate.

Moderately high indoor concentrations of carbon dioxide (CO2) can significantly impair people’s decision-making performance. Increased levels of CO2 may have particular implications for schools and other spaces with high occupant density. It has been also observed in numerous studies that higher indoor CO2 concentrations relative to outdoors are due to low rates of ventilation, which are often driven by the need to reduce energy consumption (Chao 2012).

Many international standards recommend different values for the maximum available CO2 concentration indoors. For instance, ASHRAE standard 62-1989 states that CO2 level indoors should not exceed 1000 ppm. European standard suggests that maximum level of CO2 is 3500 ppm, whereas US Agency for Safety and Health at Work claims that CO2 levels up to 5000 ppm will not cause any issues for humans even when being exposed for a long time (Etheridge et al).

To sum it up, we can see that this brief analysis demonstrates, that different sources suggest rather different values with regards to the maximum acceptable CO_2 level indoors. If we continue this analysis and look up at some local standards throughout the European countries, we may see that it has a connection with the financial stability and technology development. If higher level of CO_2 is permitted, it will translate in lower energy consumption of a building and vice versa.

While exercising or doing some heavy work it is necessary to ensure the sufficient amount of fresh air supply into the room. Air temperature and relative humidity can be maintained without having a proper ventilation system and these parameters are very individual for sportsmen, depending on their age, weight and physical condition, whereas CO_2 level is the one indicator that is crucial in sports halls, as it may directly affect the performance of the sportsmen. Existing studies are focused on IAQ in kindergartens, schools and apartment buildings (Vatin et al., Borodinecs et al and Gorskov 2015.). Such studies shows relation between ventilation rate, energy consumption and human comfort level. However, limited studies are available on sportsmen performance under different IAQ parameters.

The importance of ventilation in fitness centers was highlighted in several studies. For example recent research (Ramos 2014) on the exposure to indoor air pollutants during physical activity in fitness centers provides extensive analysis on mechanical and natural ventilation systems working specific in large athletic halls. Similar to this research, other authors proves that both mechanical and natural ventilation systems could be efficiently used in sport halls (Priyadarsini et al.).

The objective of this study was to analyze the indoor climate in four different sports halls in Riga, Latvia and to determine the relationship between the building air change rates and the sportsmen performance in the investigated buildings.

2. Materials and Methods

Four sports halls were examined – Riga’s National Sports Manege (hall 1), Riga Lithuanian Secondary School (hall 2) and Riga Secondary School No 15. (hall 3) and sport club “Kumite” (hall 4). Each sport hall is equipped with mechanical supply/exhaust systems. However ventilation system doesn’t work in Riga’s National Sports Manege. The floor area and number of persons during competition was precisely known for three halls (Table 1).

Table 1. Additional data on sports halls.

Sports hall	Floor area, m2	Number of people per m2	Heating system	Ventilation system
Hall 1	2004	0,75	Central	Supply/exhaust
Hall 2	563	0,27	Central	Supply/exhaust
Hall 3	588	0,25	Central	Supply/exhaust
Hall 4	-	-	Central	Supply/exhaust

For indoor air quality measurements data loggers with the following parameters were used: temperature: -200°C to 70°C (±0.35°C); relative humidity: 10% to 90% (±2.5%); CO_2 level: 0 to 2500 ppm (±50 ppm or 5% of reading).

Riga's National Sports Manege was built during Soviet Union times back in 1965 and it was constructed and designed according to the architectural, structural and comfort requirements of that time. Currently the sportshall is obsolete, energy inefficient, expensive to maintain and does not meet the international standards and therefore needs to be renovated.

Fig. 1 a) Riga's National Sports Manege (hall 1); b) Riga Lithuanian Secondary School (hall 2); c) Riga Secondary School No 15. (hall 3); d) sports club "Kumite" (hall 4).

Riga Lithuanian Secondary School was built in 2001 and is equipped with modern and efficient ventilation and heating system. Sports hall hosts many local youth tournaments. Riga Secondary School No. 15 was built in 1945 and is currently one of the oldest schools in Riga. In 2003 it was completely refurbished and retrofitted with a modern sports hall which is equipped with central heating system and supply-exhaust ventilation.

CO2 concentration, relative humidity and indoor air temperature were measured inside those three sports halls. Measuring units were placed against the wall at 2m height above the floor to exclude the risk of false measurements.

Ten professional sportsmen agreed to participate in the indoor climate evaluation test in those sports halls and therefore they underwent their weekly trainings doing same exercises in these three halls so that the indoor air quality and sportsmen performance relationship could be adequately assessed. After each training session the sportsmen were asked to fill the questionnaire about their perception of the indoor air quality in each hall. They were asked to answer the following questions:

1) age, sex?
2) did you have any health problems before the training?
3) how is your overall health?
4) how did you feel at the beginning of the training?
5) how did you feel in the middle of the training?
6) how did you feel at the end of the training?
7) how do you assess the indoor air quality in the sports hall?

Depending on the sportsmen evaluation the overall assessment of the indoor air climate in each of the three sports halls was generated and linked to the sportsmen performance.

Sportsmen performance was evaluated by sum of score earned during tournament in each hall.

They were asked to evaluate indoor comfort to derive the PMV and PPD values.

The Predicted Mean Vote (PMV) is the average thermal sensation response of a large number of subjects, using the ASHRAE thermal sensation scale (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold).

Given the subjective nature of comfort, there will actually be a distribution of satisfaction among a large group of people. Equation 1 shows a mathematical relationship between the PMV and thermal load (L), metabolic rate (M).

Figure 2 shows an empirical relationship between PMV and PPD (Predicted Percentage of Dissatisfied).

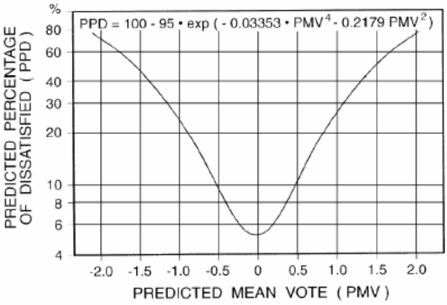

Fig. 2 Figure. 2. An empirical relationship between PPD and PMV.

3. Results and discussion

The comparison of CO2 concentration in all analyzed sport hall is shown in figure 3. Measurements were done during competitions from approximately 10.00 till 17.00.

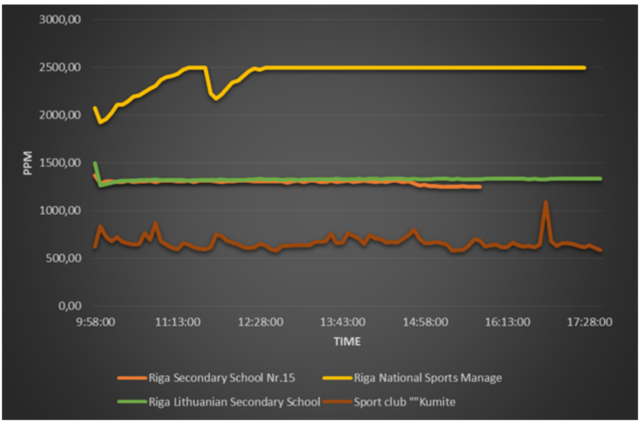

Fig. 3. Comparison of CO2 concentration in analyzed sporting halls during competitions

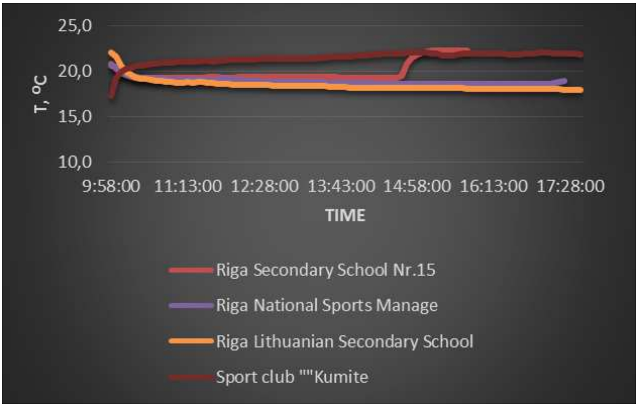

Fig. 4. Comparison of indoor air temperature in analyzed sporting halls during competitions

As it can be seen form Figure 3, the CO2 concentration exceeding 1500 ppm in Riga National Sport Manage, while most optimal CO2 level was measured in sport club “Kumite” premises. CO2 concentration in Riga Lithuanian Secondary School and Riga Secondary School No 15 was stable during competition with average value 1500ppm.
Temperature and relative humidity levels were maintained within the normal range. The maximal temperatures was reached in sport club “Kumite” with peak point 22oC. The lowest temperature range were measured at Riga Lithuanian Secondary School. Sportsmen performance during the competitions were evaluated by total number of score obtained during the fights.

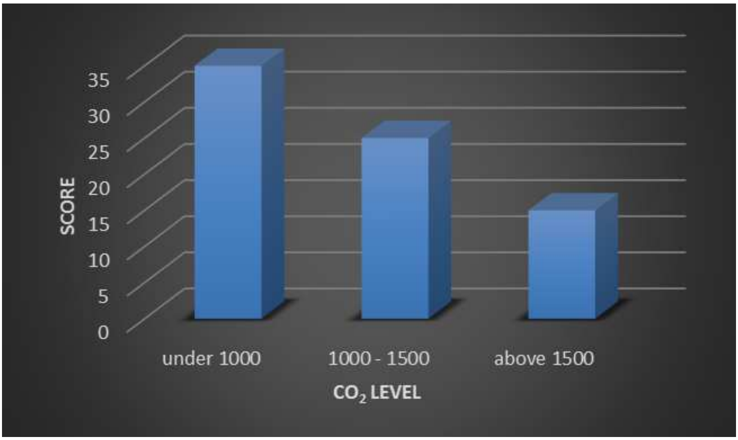

Fig. 5. Comparison of indoor air temperature in analyzed sporting halls during competitions.

4. Conclusions

In this study four sports halls with similar heating and ventilation system, but different sportsmen density per area were examined.

It was also observed, that both temperature and relative humidity levels maintained within the normal range and therefore did not pose any effect on the sportsmen performance.

Analysis of questionnaires have shown that sportsmen feel relatively comfortable if the CO_2 concentration does not exceed 1500 ppm, whereas at the CO_2 levels exceeding 1500 ppm sportsmen experienced slight headache, drowsiness and fatigue even at early stages of the physical exercising. These factors led to noticeable underperformance.

The study has clearly proven that an insufficient air exchange is leading to the increase of the CO2 levels and thus, lowering the sportsmen performance.

Seeking to reduce the energy consumption in buildings, the need for a sufficient ventilation air exchange is often compromised, which leads to rise in CO_2 levels and makes it difficult or even impossible to control the CO2 levels indoors.

It is critically important to ensure a regular air exchange in sports halls, replacing stuffy air with and fresh supply air and thus maintaining CO_2 levels under 1000-1500 ppm.

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