

HOW MUCH AIR IS NEEDED TO VENTILATE THE GYM? – CASE STUDY

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ABSTRACT:

In order to design a ventilation system based on the volumetric airflow rate, which will ensure satisfactory indoor air quality and, at the same time, do not oversize the system, it is necessary to know the quantities of pollutants emissions. The concentration of produced pollutants allows the calculation of the required fresh air volumetric flow rate. Two previous published studies are analysed in this article, whose results complement each other. From the calculated values, the graphical dependence between the required fresh air volumetric flow rate and the level of physical activity was developed. It was noticed that, according to the Slovak and Romanian legislation, for the studied gym, there is insufficient air ventilation. At an allowed maximum CO₂ concentration level of 1,000 ppm, the required fresh air volumetric flow rate, according to legislative requirements, will ensure a percentage of only 75.59% to 23.25% of the necessary rate (depending of the type of physical activity). For a lower allowed maximum CO₂ concentration level, the ensured fresh air volumetric flow rate will be even smaller. The aim of the article is to contribute to the development of healthy environments in fitness centres and gyms and to optimize the design requirements for their ventilation systems.

1. INTRODUCTION

Regular physical activity promotes both mental and physical health. It is beneficial for people of all ages and abilities to improve health, and it is never too late to start being more active and less sedentary. According to the latest WHO report, 81% of adolescents and 27.5% of adults do not meet WHO's recommended levels of physical activity and this affects not only individuals and their families over their life span, but also the health services and the society as a whole (European University Sports Association 2022). The survey of physical activity in Europe (European University Sports Association 2022) shows that 38% of Europeans play sport or exercise at least once a week or more, while 17% exercise less than once a week. Up to 45% of Europeans currently never exercise or partake in physical activity, as seen in Table 1.

The survey also revealed that during COVID-19 pandemic, half of Europeans reduced their activity levels or even stopped it altogether. According to the study (European Union 2022), 13% of Europeans do not walk at all for more than 10 minutes at a time in a weekly period, while 11% sit for more than 8.5 hours per day. 61% Europeans walked for at least 10 minutes at a time on 4 or more days in the week before the survey.

A majority of respondents (43%) report that they sit between 2 h 31 min and 5 h 30 min on a usual day, but slightly more than one in 10 (11%) sit for more than 8 h 30 min. Nearly half of Europeans who exercise, play sport or engage in physical activities, the most popular choice being outdoors (parks, sport grounds, etc.).

According to the report (European Health & Fitness Market Report, 2022), European membership population increased by roughly 1 million members (or 2%, from 55.2 million in 2020, to 56.3 million by year end 2021). The Romanian Health & Fitness Market is estimated at around 812,000 members and has seen double-digit annual growth over the past 5 years. The same trends that influenced the European Health & Fitness Market drove growth in the Romanian market as well. In addition, several local trends are visible, mainly in Bucharest and a few other major cities (Cluj-Napoca, Timișoara, Iași). While growing fast, the market is still immature, with significant development potential going forward. By 2023, it is expected a 30÷35% increase versus 2018 (Romanian Health & Fitness Market, n.a.).

The given statistics are only informative for us. The reality can be completely different. Overall, however, we can state that the number of trainee and fitness centres is increasing.

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	Population			Gross domestic product per capita (\$)	Non-communicable diseases mortality (%)	Physical inactivity					
	Total (pers)	Aged <20 (%)	Aged >60 (%)			Adolescents aged 11-17 (%)		Adults aged 18+ (%)		Adults aged 70+ (%)	
						Male	Female	Male	Female	Male	Female
Belarus	9,535,000	22	25	20,238	93	?	?	14	14	23	25
Czech Rep.	10,494,000	21	26	41,608	89	73	82	28	34	42	50
Hungary	9,968,000	20	26	33,274	94	74	86	33	43	48	59
Poland	39,858,000	20	25	34,287	90	74	84	32	33	46	49
Romania	19,660,000	21	24	32,202	91	73	87	32	38	47	54
Slovak Rep.	5,644,000	21	23	31,356	89	66	78	31	38	46	54
Ukraine	39,702,000	20	26	13,087	92	71	83	19	20	30	33

Table 1. Selected data from Global Status Report on Physical Activity 2022: country profiles (World Health Organization, 2022)

From the point of view of the designing of ventilation systems, when national regulations and standards are used, this may be a new type of approach. The new equipments used today in gyms and fitness clubs were not available when the original standards were created. Also, the dimensions of gyms and fitness clubs sometimes do not correspond to the dimensions of the exercise rooms considered in the original regulations.

For this reason, it is appropriate to calculate the required fresh air volumetric flow rate for the average exercising person according to the activity performed in the given room. The required fresh air volumetric flow rate can be significantly greater than the values specified in National regulations and standards.

2. METHODS

The aim of the article is to develop a comparison of the required fresh air volumetric flow rate for a selected model gym, which is determined according to the legislative requirements in Romania and Slovakia, the measured CO₂ concentration (Kapalo et al., 2021, Kapalo et al., 2020a) and the new methodology published in the study (Persily and de Jonge, 2017). The required fresh air volumetric flow rate comparison is made for a selected model gym with a floor area of 200 m² and a room height of 3 m. According to (Neufert E., Neufert P. and Kister, 2012) we can consider 40 practicing persons in the gym. Thus, 5 m² of surface area and 15 m³ of gym volume correspond to an average person exercising.

2.1 Determination of the required fresh air volumetric flow rate according to the legislative requirements

Legislative requirements in Slovakia. In Slovakia, Decrees 525/2007 (Decree 525/2007), 101/2019 (Decree 101/2019) and 75/2023 (Decree 75/2023) apply to gyms. According to the Decree 525/2007 (Decree 525/2007) and 101/2019 (Decree 101/2019), the required temperature in the gym is 16°C and the recommended air exchange in the room is 3 exchange rate/h. In the case of our selected gym, the total ventilation airflow volume is 1,800 m³/h. Decree 75/2023 (Decree 75/2023) is valid for school gyms for children and youth up to 18 years of age, which requires 4 m² (8 m² in the case of area-demanding sports). The temperature in the gym is required to be 15°C. The required airflow ventilation rate is 30 m³/h per person. If people under the age of 18 were to exercise in the sample gym, a total ventilation airflow volume of 1,200 m³/h is required.

Legislative requirements in Romania. According to I5-2022 prescriptions - Annex 7 (I-5 2022), the recommended air exchange in the room is between 2 and 3 exchange rate/h. This gives, for the considered gym, a total ventilation airflow volume of 1,200 ÷ 1,800 m³/h. The second alternative, in compliance with I5-2022 prescriptions - Chapter 4.3 (I-5 2022), is calculated according to the required 7 l/s air ventilation/person plus 0.7 l/s per m² of gym floor area for a new or renewed building (IDA 2), and gives a total ventilation airflow volume of 1,512 m³/h.

2.2 Determination of the required fresh air volumetric flow rate according to the measured CO₂ concentration

To determine the required fresh air volumetric flow rate in the room it is possible to use the theoretical knowledge about the air volume required to dilute the quantities of gaseous pollutants - in our case, the concentration of CO₂. The calculation methodology is presented in the article (Kapalo and Siroczki, 2014).

During physical activity of persons in the room, the concentration of CO₂ is recorded. The CO₂ emissions are calculated from the measured CO₂ concentration values and then the required fresh air volumetric flow rate for the room is calculated.

The maximum CO₂ concentration value in the room is equal to 1,000 ppm and was established to ensure the indoor air freshness. This maximum value can be reduced so that the difference between the CO₂ concentration in the room and in the outside air is in the range of 400 ÷ 600 ppm. This means that with a CO₂ concentration in the outside air of 400 ppm, it is advisable to have a maximum concentration in the room ranging from 800 to 1,000 ppm. With a CO₂ concentration in the outside air of 600 ppm, it is possible to have a maximum concentration of 1,000 ppm in the room.

In this study, we used the results obtained from experimental measurements, which were published in articles (Kapalo et al., 2021, Kapalo et al., 2020a). The models of the rooms used for the experimental measurements are presented in Figures 1 and 2.

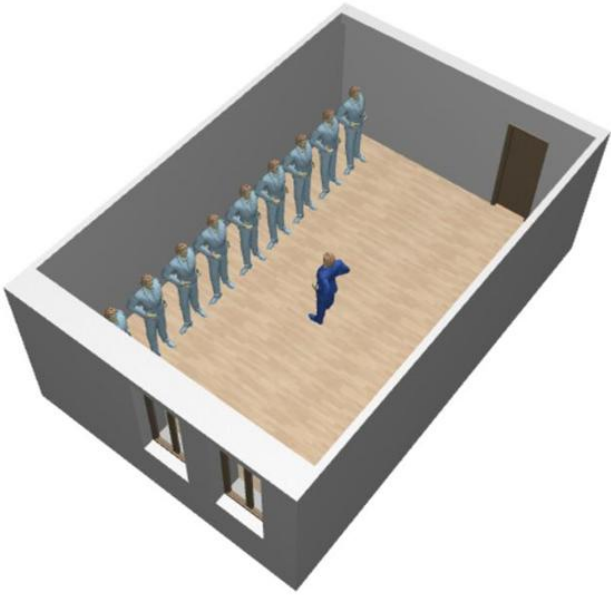


Figure 1. Model of gym - Various exercises

In studies (Kapalo et al., 2021, Kapalo et al., 2020a) the rate of CO₂ production was investigated for exercising people at different levels of activity intensity, ranging from 1.98 to 8.80 MET. Some exercises which were performed in the gym are presented in Table 2. In the case of the studied gym, it was concluded that the CO₂ production rate increases linearly with the level of physical activity.

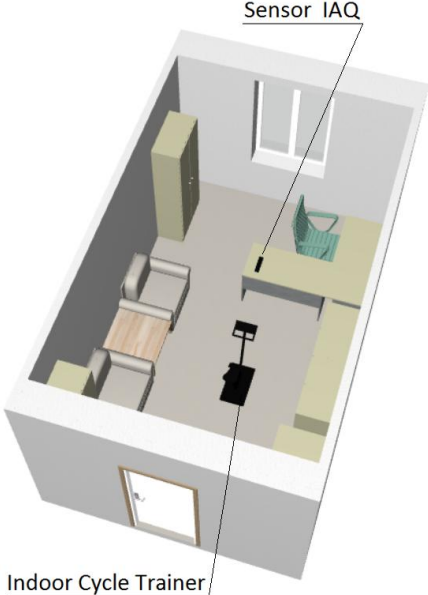


Figure 2. Room model - Stationary bicycle

In order to determine the required fresh air volumetric flow rate to ventilate the gym, experimental measurements were performed. During the first experimental group measurements, there were persons in the first room who performed the selected exercises. A total of 5 sets of exercises were performed, presented in Table 2. During the second experimental measurements, there was one person in the second room (Figure 2) who was exercising on the stationary bicycle.

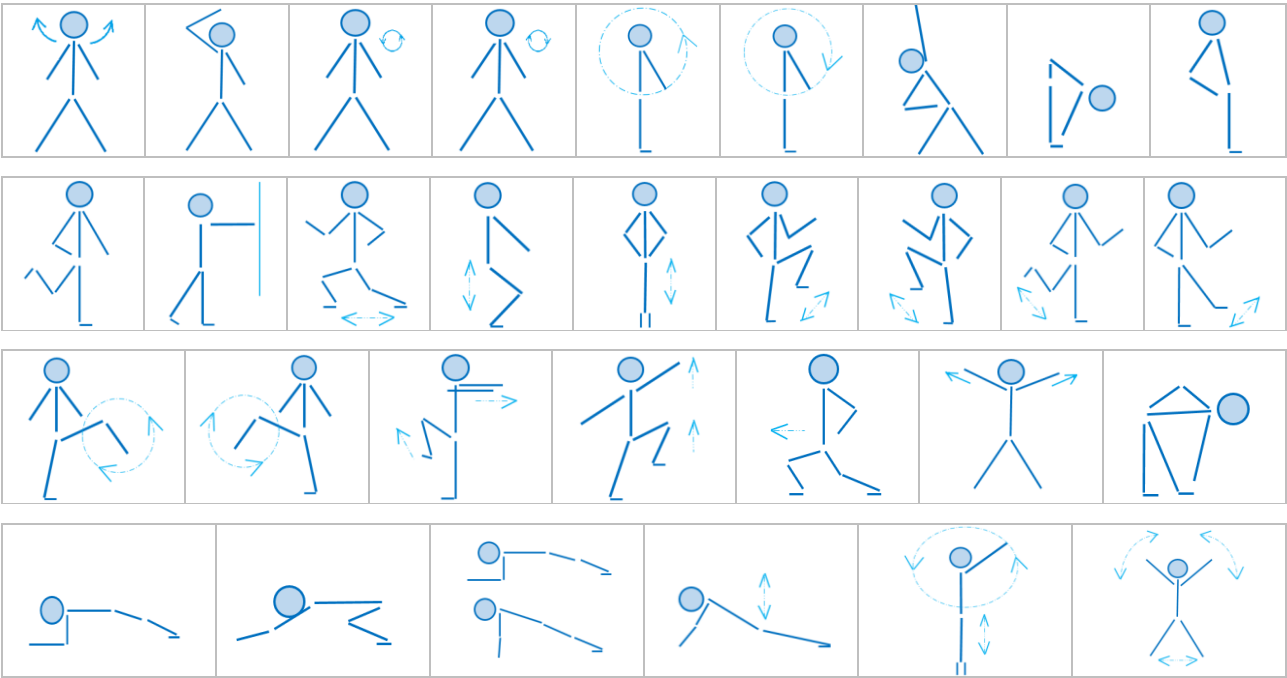


Table 2. Description of selected exercises performed by people in the gym

3. RESULTS AND DISCUSSIONS

During the entire period of the experimental measurements, the following indoor air parameters were recorded in the rooms: temperature, relative humidity and CO₂ concentration. From the measured air parameters, the CO₂ emission mass-flow rate was calculated, and then the required fresh air volumetric flow rate for the room was determined. The calculated values of CO₂ emissions generated from the gyms (Kapalo et al., 2021, Kapalo et al., 2020a) were compared to other research work in the field (Wu et al., 2023, Persily and de Jonge, 2017). The authors of first study (Wu et al., 2023) confirmed in their research that the CO₂ emission rate increases with the increase in the activity

levels. Age has a significant effect on CO₂ emissions. The gender differences become apparent after age 15 - the rate of CO₂ production in boys begins to be significantly higher than in girls (Wu et al., 2023). The authors of the second study (Persily and de Jonge, 2017) proposed a model to estimate the CO₂ emission rates using basal metabolic rate (BMR), including weight, age, and gender factors. All CO₂ emission rate values obtained from studies (Kapalo et al., 2021, Kapalo et al., 2020a, Persily and de Jonge, 2017, Wu et al., 2023) are documented in Figure 3.

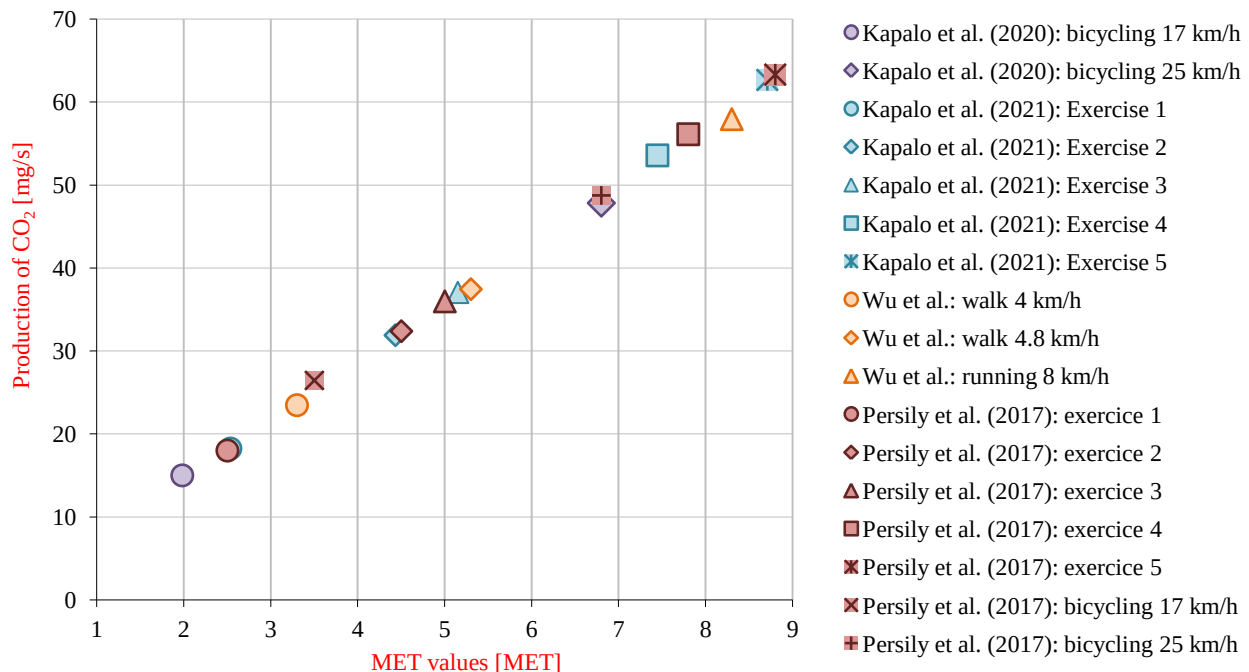


Figure 3. Comparison of the CO₂ production values

From Figure 3 it is possible to observe that the emissions of CO₂ are linearly dependent with the level of physical activity of the persons. From the marked points, a linear dependence was determined, expressed by the following equation:

$$q_{ms} = 7.059 \cdot M + 0.6098 \quad [\text{mg/s}] \quad (1)$$

where q_{ms} = CO₂ production rate [mg/s]
 M = physical activity level [MET]

The equation is represented graphically in Figure 4.

The standard deviation of CO₂ emission values obtained from studies (Kapalo et al., 2021, Kapalo et al., 2020a, Persily and de Jonge, 2017, Wu et al., 2023) and from the calculated values, according to equation (1), is 0.58. The calculated deviations are in the interval from -1.28 to 1.12. The calculated standard error is 0.14.

According to (Persily, 2022), the indoor CO₂ concentrations depend primarily on the rate at which the occupants produce CO₂, the outdoor air ventilation rate of the space, the time since occupancy began, and the outdoor CO₂ concentration.

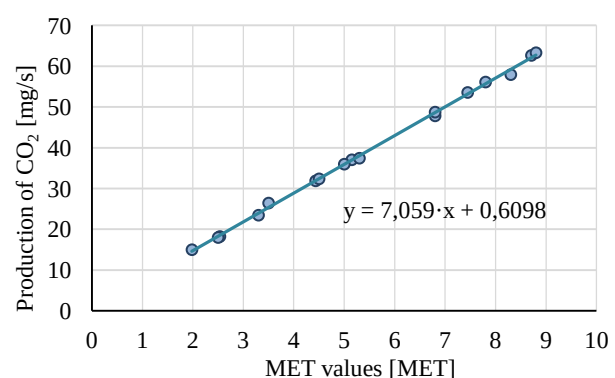


Figure 4. The CO₂ production

From all of the CO₂ emission values obtained from studies (Kapalo et al., 2021, Kapalo et al., 2020a, Persily and de Jonge 2017, Wu et al., 2023), the required fresh air volumetric flow rate was calculated [m³/h]. The results of the calculation are processed into a graph in Figure 5, where the dependence between the required fresh air volumetric flow rate and the intensity of physical activity for an average person in the gym is presented.

From Figure 5 it is possible to determine the required fresh air volumetric flow rate needed to ventilate the gym, per person at different indoor CO₂ concentrations, for various levels of physical activity [MET].

According to the Slovak and Romanian legislative requirements for the ventilation of the selected gym (floor area of 200 m², gym volume of 600 m³, in which approximately 40 people are supposed to exercise), the needed fresh air volumetric flow rate is between 1,200 m³/h and 1,800 m³/h (the red and brown horizontal lines in Figure 5).

According to the calculated CO₂ emission rate, for the studied gym, the required fresh air volumetric flow rate is between 2,000 to 8,359 m³/h, depending on the level of the physical activity of the exercisers. Values are considered for a maximum

CO₂ concentration of 1000 ppm. For lower CO₂ concentrations in the studied gym, the needed fresh air volumetric flow rate will be larger. The results of the required fresh air volumetric flow rate are presented in Figure 5. It can be observed that, according to the Slovak and Romanian legislation, for the studied gym which is designed according to (Neufert E., Neufert P. and Kister, 2012), there is an insufficient air ventilation. In the case of ventilation of the studied gym, when the maximum CO₂ concentration level of 1,000 ppm will be allowed, the required fresh air volumetric flow rate, according to legislative requirements, will ensure a percentage of only 75.59% to 23.25% of the necessary rate (depending of the type of physical activity). In the case of a maximum CO₂ concentration level of 900 ppm or 800 ppm, the ensured fresh air volumetric flow rate will be even smaller.

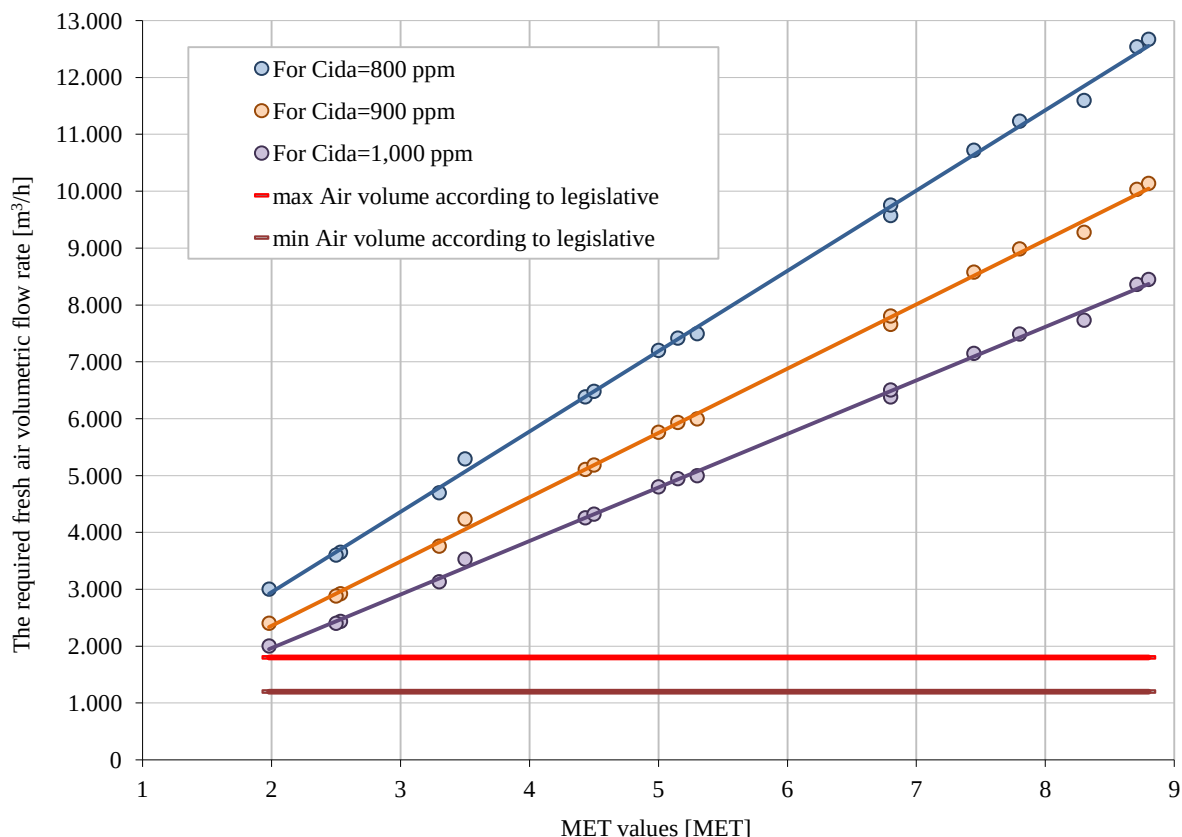


Figure 5. The dependence of the required fresh air volumetric flow rate on the physical activity of a person in the gym

With these considerations, it is necessary to remind that the CO₂ concentration level is not the only condition to determine the required fresh air volumetric flow rate. In the case of a gym, it can be the excess of smell, dust, humidity, temperature or other substances (Wargocki et al., 2021, Teichman et al., 2015, Benjamin Jones, 2017, Kapalo et al., 2020b, Kapalo, Klymenko, Zhelykh and Adamski, 2020). According to (Persily, 2022), it is necessary to take into account the level of CO₂ concentration individually, in different types of rooms.

4. CONCLUSION

In the last years, the number of different size gyms has increased, in which it is possible to perform exercises with various levels of physical activity, from least to more

demanding. This study confirms that with the increase of the difficulty level of physical exercises, the required fresh air volumetric flow rate also rises. The results from four studies are analysed in the article, which confirm a linear increase of CO₂ mass flow production in the gym, depending on the level of physical activity. At the same time, the need to adjust the legislative requirements regarding the ventilation rates for gyms is pointed out. The article presents a graphical dependency created to establish the required fresh air volumetric flow rate in accordance with the level of physical activity, which can be used when designing a gym ventilation system. Consequently, this will contribute to the creation of healthy environments in gyms and to the adjustment of the design requirements for their ventilation systems.

Future studies will need to take into consideration other types of gyms configurations, as well as the presence of different other substances in the gyms, corresponding with the performed exercises.

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