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IMPROVING VENTILATION IN THE FITNESS CENTER

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A physical model of ventilation of a fitness hall has been developed under conditions of varying visitor load and intensity of physical exercise. The ventilation rate of a fitness room and required amount of supply ventilation air when forming comfortable microclimate in a room under conditions of different intensity of physical exercises were determined. The results of experimental and theoretical studies of dependence of multiplicity of supply and exhaust ventilation depending on the number of visitors to the fitness hall, taking into account intensity of their physical activity and the value of internal air temperature are presented. The method of determining the volumetric and mass flow rate of supply ventilation air and the ventilation rate depending on temperature of the indoor air, carbon dioxide concentration, atmospheric pressure, number of visitors, their gender, age and intensity of physical exercises has been improved.

Keywords: fitness center, ventilation, physical activity, volume flow, air temperature, ventilation rate.

Introduction

Recently, several fitness centers and gyms have been established in new buildings or in renovated ones (Dovhaliuk and Mileikovskyi, 2018; Lorin at al., 2007). Since these are operations whose goal is to maintain or improve the health of people, one of the main requirements is to ensure the required quality of the indoor environment – including the quality of indoor air (Kapalo et al., 2014; Kapalo et al., 2017). In order to achieve the required indoor air quality, it is necessary to correctly determine the volume flow of ventilation air for the purpose of energy-efficient optimization of the ventilation and air conditioning system in the building (Rumsey and Spalart, 2009). It is also necessary to meet the relevant legislative requirements. The quality of indoor air in rooms intended for sports is addressed by several studies around the world, which point to problems associated with ventilation deficiencies (Srebric and Chen, 2002).

Nowadays, the issue of ventilation intensity in fitness centers is relevant.

The purpose of the article is to study the physical model of ventilation of the fitness center premises and to establish graphical dependencies and analytical equations for determining the ventilation rate under the condition of creating a comfortable microclimate in the premises of fitness centers.

The fitness assessed was designed according to (Neufert et al., 2012; Voznyak et al., 2019). The floor area is 80 m^2, the clear height of the room is 3 m and the volume of the room is 240 m^3.

Materials and methods

The equipment with exercise equipment is not decisive in this case since the subject of the analysis is the intensity of the room ventilation (Fig. 1). The number of people exercising in fitness was designed according to (Neufert et al., 2012; Smith, and Milton, 2007) and is given in Table 1, where the number of men and women of different age categories is given. Data on the weight of people are processed according to (Glassman et al., 2023; Mackelden et al., 2023; Fryar et al., 2018).

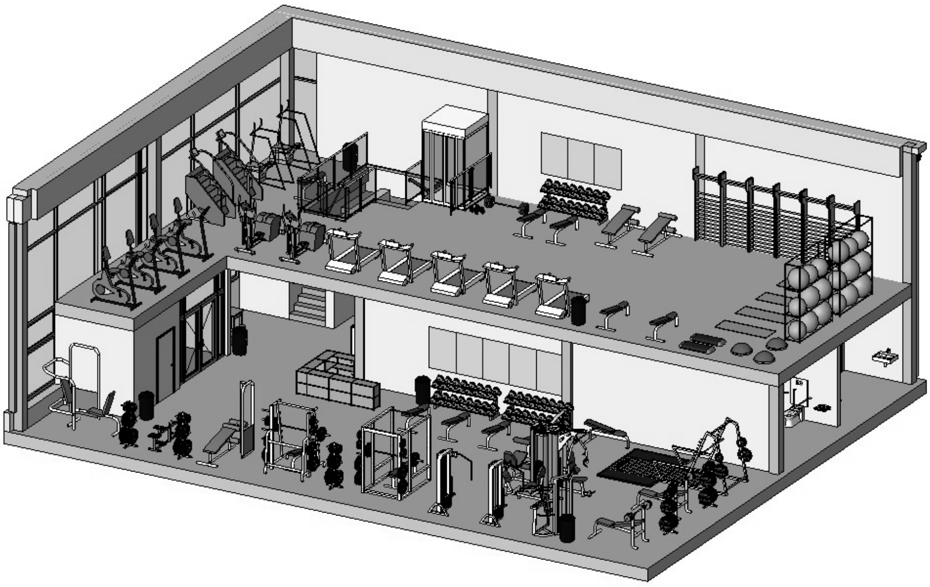

Fig. 1. Fitness room

The weights of people with excess weight were deliberately chosen, because according to (Kapalo et al., 2018) people with greater weight produce greater amounts of CO_2, who need more ventilation air (Janbakhsh, S. and Moshfegh B., 2014).

They are of different ages, weights and genders (Table 1) and are engaged in different intensities – *M* = 100 – 200 met (Table 2).

Table 1

Characteristics and number of trainees

Age	Weight		BMR		Number of people in the fitness center	
	men	women	men	women	men	women
	kg	kg	MJ/day	MJ/day	–	–
20–29	85.55	76.02	8.29	6.75	2	2
30–39	94.39	76.02	8.18	6.12	2	2
40–49	93.85	80.01	8.16	6.26	2	2
50–59	91.85	80.01	8.06	6.26	2	2
60–69	91.26	75.52	6.93	5.62	2	1
70–79	87.72	75.52	6.76	5.62	1	0
80 ≥	80.51	75.52	6.40	5.62	0	0
Total number of people					11	9

Table 2

Selected physical activities

Physical activity level, M met	Activity description
2.3	Easy effort
3.5	Cycling on a stationary bike, 30–50 W. Weight training; very light to light effort
5.0	Weight training. Squats, slow pace. Elliptical trainer, moderate effort
8.8	Cycling on a stationary bike, 101–160 W, increased effort. Deep digging with a weight of 7.26 kg/min
12.0	Stationary rowing, 200 W, very fast pace

In the proposed rooms, it is assumed that the exercisers will perform exercises with a level of physical activity in the range $M = 2.3 \div 12.0$ met, which are listed in the compendium of physical activities in section 02 – fitness exercises https://sites.google.com/site/compendiumofphysicalactivities/ Activity-Categories (Ainsworth et al., 2018; Ainsworth et al., 2011; Gumen et al., 2019).

Examples of selected physical activities are listed in Table 2.

Results and discussion

When determining the ventilation intensity, CO_2 volumetric flows were calculated based on the body parameters of the subjects according to the methodology of (Persily et al., 2017; Nösslinger et al., 2021). Equation (1) was used.

$$V_{CO_2} = BMR \cdot M \cdot (T/P) \cdot 0.000179, \quad (1)$$

where V_{CO2} is the volume flow of CO_2 produced, l/s; *BMR* is the basal metabolic rate, MJ; *M* is the level of physical activity, met; *T* is the room air temperature, K; *P* is the atmospheric air pressure in the room, kPa.

The calculation took into account the air temperature in the room in summer of 26 °C and in winter of 18 °C and the air pressure in the room in summer of 98.87 kPa and in winter of 98.35 kPa. The level of physical activity *M* was determined from 2.3 met to 12.0 met – see Table 2.

From the CO_2 volume flow, the CO_2 mass flow, mg/ (s. person) was calculated according to equation 2.

$$q_{m,CO2} = \rho_{CO2} \cdot V_{CO2}, \ \text{mg/s} \quad (2)$$

where qm, CO_2 is the mass flow of CO_2, mg/s; ρCO_2 is the density of CO_2, g/m^3 and V_{CO2} is the volume flow of CO_2 produced, l/s.

The density of CO_2 depends on the temperature and pressure of the air in the room. We calculate it using the gas equation of state:

$$\rho_{CO2} = \frac{p \cdot M}{R \cdot T}, \quad (3)$$

where ρ_{CO2} is the density of CO_2, g/m^3; *M* is the molar mass of CO_2, g/mol, M_{CO2} = 44.01 g/mol (13); *R* is the molar gas constant, *R* = 8.314 472 J/(K.mol); *p* is the room air pressure, Pa and *T* is the room air temperature, K.

The ventilation air volume flow rate required to ensure the required indoor climate in the fitness room was calculated using equation (4), assuming a CO_2 concentration of the outdoor ventilation air of 400 ppm and a required indoor CO_2 concentration of 900 ppm

$$q_V = \frac{q_{m,CO2}}{C_{IDA} - C_{SUP}}, \quad (4)$$

where q_v is the required ventilation air volume flow rate, m^3/s; q_m, CO_2 is the CO_2 mass flow rate, mg/s; C_{IDA} is the required indoor CO_2 concentration, mg/m^3 and C_{SUP} is the ventilation air CO_2 concentration, mg/m^3.

To determine the conversion factor from “ppm” to “mg/m^3”, it is necessary to proceed according to Avogadro’s law. The conversion factor from CO_2 concentration units “ppm” to “mg/m^3” is given by the ratio of the molar volume and molar mass of the pollutant under consideration.

$$k = \frac{V_{m,CO2}}{M_{m,CO2}}, \quad (5)$$

where $V_{m, CO2}$ is the molar volume of CO_2, l/mol and $M_{m, CO2}$ is the molar mass of CO_2, g/mol.

The molar mass of the pollutant under consideration (CO_2) for the standard state: Θ = 0 °C; p = 1.01325 bar, is $M_{m,\ CO2}$ = 44.01 g/mol. From the ideal gas equation, it is possible to calculate the molar volume of the ideal gas:

$$V_{m,CO2} = \frac{V}{n_m} = \frac{R \cdot T}{p}, \tag{6}$$

where R is the molar gas constant, R = 8.314 463 J/(mol.K); T is the thermodynamic temperature, K; p is the pressure, kPa and n_m is the number of moles of gas, mol.

For temperature T = 293.15 K (20 °C) and pressure 100 kPa, the molar volume of an ideal gas is V_m = 24.37 l/mol according to formula (6). After substituting into formula (5), we obtain the unit conversion coefficient K. The CO_2 concentration in units of "mg/m^3" is obtained by dividing the CO_2 concentration given in units of "ppm" by the coefficient k = 0.554.

The resulting values of ventilation air volume flow for the assessed fitness depending on the level of physical activity are documented in Fig. 2.

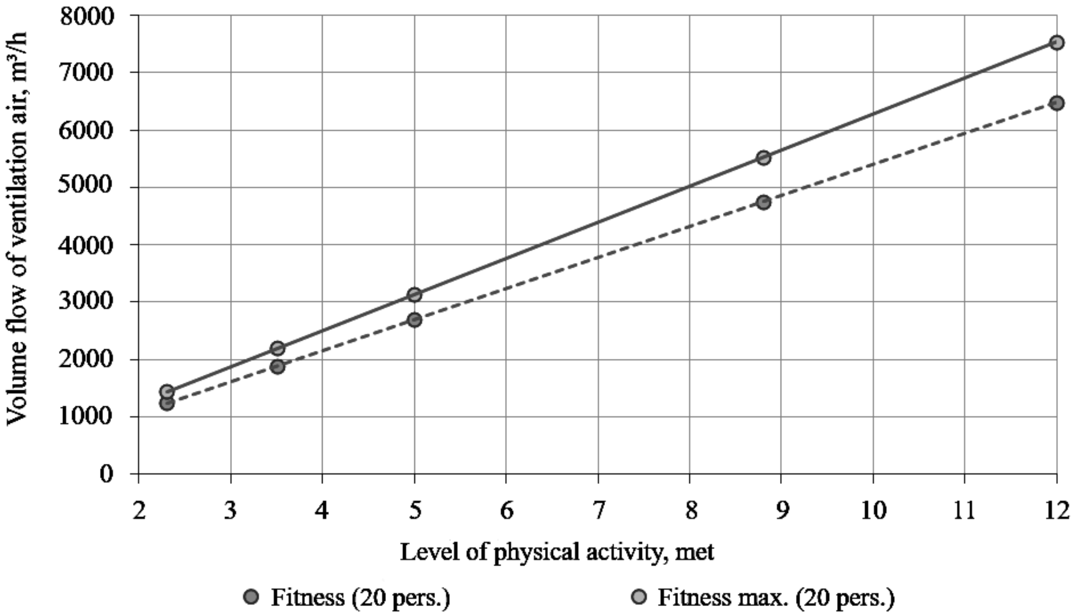

Fig. 2: *Ventilation air volume flow rate depending on the level of physical activity*

In Fig. 2, the dashed lines document the required ventilation air volume flow rates for the persons listed in Table 1. The solid line documents the required ventilation air volume flow rate in the fitness room for the maximum permitted number of persons in the fitness room (20 persons) whose CO_2 production is maximum – i. e. men aged 20 to 29 years.

The room ventilation intensity was calculated using formula 7 from the calculated required ventilation air volume flow rate in fitness and for physical activity levels from M = 2.3 met to M = 12.0 met.

$$n = \frac{q_V}{V}, \tag{7}$$

where n is the ventilation rate, 1/h; q_V is the required ventilation air volume flow rate for the given zone or room, m^3/h and V is the air volume in the zone or room, m^3.

In order to compare the calculated ventilation air volume flow rates with the legislative requirements, the ventilation intensity was also calculated according to Decree 525/2007, ASHRAE standard 62-2022 (16) and NL-Actief (17). The resulting values of the ventilation intensity for fitness depending on the level of physical activity are documented in Fig. 3.

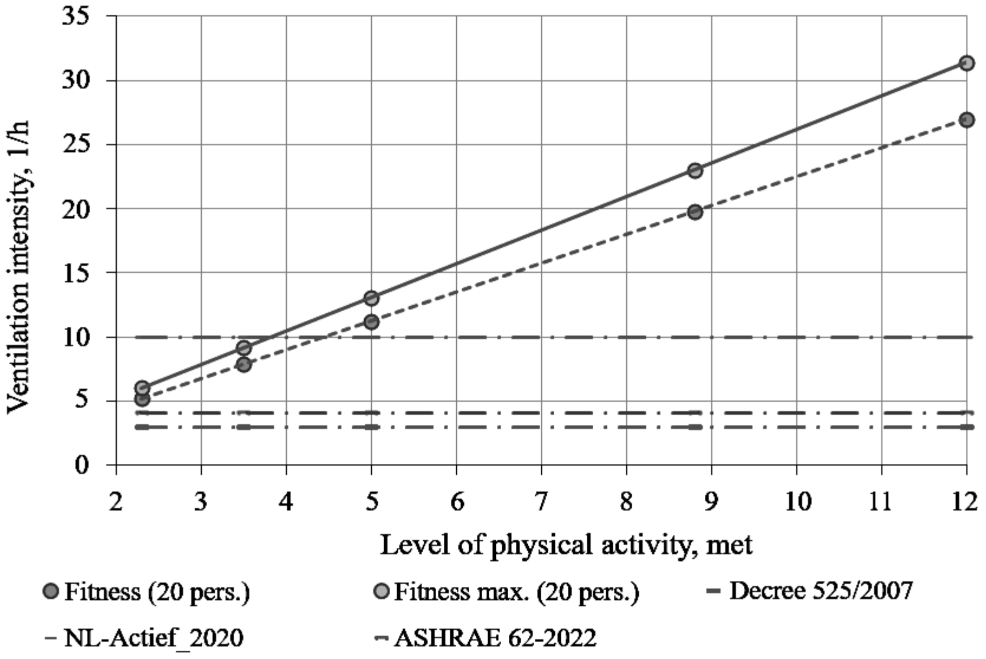

Fig. 3. Ventilation intensity depending on the level of physical activity

From the resulting ventilation intensity values documented in Fig. 3, it can be concluded that the Slovak Decree 525/2007 is not suitable for designing a ventilation system in the assessed fitness, because at the indicated levels of physical activity, 3-fold air exchange is insufficient. The calculation methodology according to ASHRAE 62-2022 is also not suitable. The methodology according to NL-Actief (10-fold air exchange) is suitable only for the level of physical activity up to M = 4.5 met.

If the assessed fitness facility required a 3-fold air exchange according to Decree 525/2007 and at the same time, exercises should be performed by men aged 20 to 29 with a physical activity level of up to M = 12.0 met, then a maximum of two people could exercise in the assessed fitness facility.

Conclusions

Given the level of physical activity performed in the assessed fitness, Decree 525/2007 is not suitable for determining the ventilation intensity.

In fitness, it is recommended to design the ventilation intensity using the methodology of Persila and de Jonge.

It is assumed that the above calculation procedure can be processed in software and used in modeling programs used in the design of air-conditioning systems in buildings.

Prospects for future research

Future research can be connected with ventilation research of cult buildings. Some conditions are similar and some ones – different. This question would be interesting.

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ВДОСКОНАЛЕННЯ ВЕНТИЛЯЦІЇ У ФІТНЕС-ЦЕНТРІ

Вирішено актуальне завдання вдосконалення вентиляції у приміщеннях фітнес-центрів. Метою статті є дослідження фізичної моделі вентиляції приміщень фітнес-центру та встановлення графічних залежностей, а також аналітичних рівнянь, щоб визначити інтенсивність вентиляції за умови створення комфортного мікроклімату в приміщеннях фітнес-центру. Розроблено фізичну модель вентиляції приміщення фітнес-центру за умови різноманітної кількості відвідувачів та різної інтенсивності виконуваних фізичних вправ. Результати експериментальних досліджень наведено у вигляді графіків та теоретичних формул, які доповнено отриманими поправними коефіцієнтами. Визначено як кратність вентиляції приміщення фітнес-центру, так і кількість повітря припливно-витяжної вентиляції, необхідну для формування комфортного мікроклімату у приміщенні фітнес-центру за різноманітної інтенсивності фізичних вправ. Викладено результати теоретичних та експериментальних досліджень залежності кратності припливної та витяжної вентиляції від кількості відвідувачів залу фітнес-центру, враховуючи інтенсивність їхніх фізичних навантажень та температуру внутрішнього повітря. Удосконалено методику визначення об'ємної та масової витрат припливного вентиляційного повітря, а також кратності вентиляції залежно від температури внутрішнього повітря, концентрації вуглекислого газу, атмосферного тиску, кількості відвідувачів, їх статі, віку та інтенсивності виконуваних фізичних вправ. Виконано порівняння отриманих експериментальних даних із теоретичними розробками. Встановлено, що кількість припливного повітря та кратність вентиляції істотно зростають зі збільшенням кількості людей та інтенсивності виконуваних фізичних вправ, а з підвищенням температури внутрішнього повітря та атмосферного тиску зростають значно менше.

Ключові слова: фітнес-центр, вентиляція, фізична активність, об'ємна витрата, температура повітря, кратність вентиляції.