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EDUCAÇÃO FÍSICA / PHYSICAL EDUCATION

Fitness centers demonstrate CO_2 concentration levels above recommended standards

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ABSTRACT. This study aims to compare carbon dioxide (CO_2) concentration levels measured in fitness centers with the applicable guidelines from Brazil, France, and Europe. Three fitness centers in Florianopolis, Santa Catarina State, Brazil (fitness centers A, B, and C) participated in this study. The fitness centers have different physical characteristics and ventilation systems. Fitness centers A and B have split ventilation systems, while fitness center C has a central ventilation system. The air quality was assessed by determining the CO_2 concentration level, as measured by a non-dispersive infrared CO_2 concentration sensor. Data was analyzed with descriptive and inferential statistics. All three fitness centers recorded CO_2 concentrations significantly above ($p = 0.00$) the maximum level of 750 ppm recommended by the European standard. Fitness centers A ($\bar{x}$ = 3752.13 ppm) and C ($\bar{x}$ = 1360.89 ppm) also had CO_2 concentrations significantly above ($p = 0.00$) the maximum level of 1000 ppm recommended by the Brazilian and French guidelines. CO_2 concentrations in fitness centers were significantly above the maximum permitted levels. Besides suggesting inefficient ventilation in these fitness centers, high CO_2 concentrations can impair indoor air quality and increase risks to the health of practitioners.

Keywords: air pollutants; carbon dioxide; fitness centers; motor activity.

Academias de musculação e ginástica apresentam níveis de concentração de CO_2 fora da norma recomendada

RESUMO. O objetivo do presente estudo foi comparar os níveis de concentração de dióxido de carbono (CO_2), em academias de musculação, com as normas estabelecidas no Brasil, França e na Europa. Participaram do estudo três academias de musculação (A, B e C) de Florianópolis/SC. As academias A e B são ventiladas com split system e a academia C é ventilada com sistema central. O parâmetro medido para avaliação da qualidade do ar foi a concentração de CO_2. Para determinar as taxas de emissão de CO_2 no ambiente, foi utilizado um sensor de concentração de CO_2 não dispersivo por infravermelho. Os dados foram tratados com estatística descritiva e inferencial. As três academias investigadas apresentaram níveis de concentração de CO_2 significativamente acima ($p=0,00$) da norma Europeia (750 ppm). As academias A ($\bar{x}$ = 3752,13 ppm) e C ($\bar{x}$ = 1360,89 ppm) apresentaram níveis de concentração de CO_2 significativamente acima ($p=0,00$) dos parâmetros recomendados pelas normas brasileira e francesa (1000 ppm). Conclui-se que as academias investigadas apresentam concentração de CO_2 significativamente acima dos níveis máximos permitidos. Estas concentrações de CO_2, além de serem um indicador da baixa adequabilidade da ventilação, prejudicam a qualidade do ar e podem colocar em risco a saúde dos praticantes.

Palavras-chave: poluentes do ar; dióxido de carbono; academias de ginástica; atividade física.

Introduction

Several studies have shown the importance of evaluating indoor air quality, given that people currently spend more than 90% of their time each day indoors (Castro et al., 2015). These studies have been carried out for the most common indoor environments, such as homes (Massey, Kulshrestha, Masih, & Taneja, 2012; Wells et al. 2015), schools (Braniš, Šafránek & Hytychová, 2009; Buonanno, Fuoco, Morawska, & Stabile, 2013), hospitals (Jung, Wu, Tseng, & Su, 2015), and offices (Wolkoff, 2013).

Fitness centers are indoor environments designed for the practice of physical activities and sports and should also be the focus of air quality investigations. This sector has shown remarkable expansion in recent years, and both the number of practitioners and number of facilities have increased considerably (Barreira & Carvalho, 2007). Additionally, research has shown that indoor air quality can be more polluted than outdoor air quality (Hug, Hansmann, Monn, Krütli, & Seeland, 2008; Tan & Mulyono, 2010). Practitioners of physical activities have increased minute ventilation, inhaling more air and pollutants, and most of this air is inhaled through the mouth instead of through normal nasal mechanisms. Furthermore, the increased airflow velocity during physical exertion can carry pollutants deeper into the respiratory tract (Carlisle & Sharp, 2001).

Indoor environments frequently have higher carbon dioxide (CO_2) concentrations than the outdoor environment, and this elevated CO_2 level is a product of human respiration (Alves, Calvo, Castro, Fraile, Evtyugina, & Bate-Epey, 2013). The air we breathe contains 0.03% CO_2 (300 ppm), while expired air has 4–6% CO_2 (40–60 ppm), and that concentration increases with physical exertion (Vercruyssen, Kamon, & Hancock, 2007). Air quality in fitness centers, as in other indoor environments, is influenced by factors such as the building materials, building maintenance, and type of ventilation. However, what makes the indoor air quality in these environments unique is the type and level of physical activity and human occupation occurring within them (Ramos, Wolterbeek, & Almeida, 2014; Ramos, Reis, Almeida, Alves, Wolterbeek, & Almeida, 2015).

High CO_2 levels indicate that the internal environment is receiving a minimal amount of fresh air. Adequate ventilation is necessary to dilute and control the accumulation of pollutants. Established standards in Brazil and France recommend that for the comfort and well-being of the occupants, the CO_2 concentration indoors should not exceed 1000 ppm (France, 1978; Brasil, 2003). European Standards EN 13779 (European Committee for Standardization [CES], 2007a) and EN 15251 (CES, 2007b) recommend a more stringent limit of 750 ppm.

Studies evaluating the indoor air quality of physical exercise and sporting facilities are scarce and have mostly been conducted in gyms (Braniš & Šafránek, 2011; Buonanno et al., 2013; Alves et al., 2013). Given the growing prominence of fitness centers, and considering the trade-offs that can exist between the benefits of physical activity and detrimental effects of poor air quality in sports facilities, this study aims to compare CO_2 concentration levels in fitness centers with established guidelines from Brazil, France, and Europe. Furthermore, this study also examines the influence of the physical characteristics of the fitness centers on the observed CO_2 concentration levels.

Material and methods

The research procedures were approved by the Human Research Ethics Committee of the Santa Catarina State University in which the research was conducted, under the reference number 954.242/2015 (protocol n. 04944112.0.0000.0118). This is a descriptive field study with a cross-sectional and observational design.

Sampling sites

Three fitness centers in Florianopolis, Santa Catarina, Brazil (fitness centers A, B, and C) were investigated. These fitness centers were selected for their different physical characteristics, as shown in Table 1, as well as for their convenience of access.

Within each fitness center, the weight room was chosen as the location for the air quality observations. Weight rooms are the environments with the greatest number and turnover of users, as suggested by the fitness center owners and verified through their management systems. In the weight rooms, the only common feature among the three fitness centers was the use of air conditioning. The fitness centers differed in the number of machines available in the weight room, dimensions of the weight room, and type of air conditioning system (Table 1). Such differences are fundamental to this study because these characteristics can affect the concentration of CO_2 in the environment (Tan & Mulyono, 2010).

Table 1. Main physical characteristics of the fitness centers.

	Fitness Center A	Fitness Center B	Fitness Center C
Enrolled People ▲	389	310	700
Height (m)▲	2.6 m	4.5 m	6m
Area (m^2)▲	300.80m^2	160m^2	616m^2
Type of ventilation system	Split System	Split System	Central System
Machines in the weight room▲	55	39	97

▲Major differences between the fitness centers. Legend: m: height in meters; m^2: area in square meters.

Instrumentation

The indoor air quality (IAQ) was assessed by measuring CO_2 concentration levels. The data collection methodology as well as the reference standards for air quality in the fitness centers were based on Brazilian National Health Surveillance Agency (ANVISA) Resolution no. 9 of January 16, 2003 (Brasil, 2003).

The obtained CO_2 concentrations were compared to three different regulatory guidelines:

- In Brazil, ANVISA Resolution no. 9 (2003) provides a guideline of 1000 ppm.

- In Europe, Standards EN 15251 and EN13779 recommend a limit of 750 ppm (350 ppm above the outdoor level of 400 ppm).

- In France, regulations for non-residential buildings recommend a guideline of 1000 ppm.

A CO_2 concentration meter (AZ Instrument Corp. model AZ77535, Taichung City, Taiwan) with a non-dispersive infrared sensor of 20 to 30 Vdc and an analog output 4–20 mA was used to quantify the CO_2 concentrations.

Procedures

With the consent of the fitness centers owners, data collection was performed on the three days a week determined to have the largest number of users. The researchers installed the IAQ equipment at the beginning of each data collection day when the fitness center opened at 7:30 am and removed it again at 9:30 pm. The sampling equipment was positioned centrally in each location and placed at a height of approximately 1.5 m. In addition to the data recorded by the instrumentation, the researchers logged the CO_2 concentrations every 30 minutes in a field diary.

Statistical analysis

The data was analyzed with the Statistical Package for the Social Sciences (SPSS) software (version 20.0). Data was analyzed with both descriptive and inferential statistics. Descriptive statistics were used to determine maximum and minimum values, as well as evaluate the dispersion of the data by calculating standard deviations.

The Shapiro–Wilk normality test was used to verify the distribution of the data, and indicated that it was non-parametric in nature.

An independent t-test was used to compare the mean values of the CO_2 concentrations in the fitness centers. The comparison of the CO_2 concentrations with guidelines from Brazil, France, and Europe was also performed with a t-test for each location. The Mann–Whitney U test was used to compare the mean CO_2 concentration levels in consideration of the varying physical characteristics of the fitness centers (height of the weight room, area of the weight room, type of air conditioning system, and number of machines in the weight room). The level of statistical significance was defined as $p < 0.05$.

Results

The CO_2 concentration levels vary between the different fitness centers ($p < 0.01$). The highest mean CO_2 concentration was measured in fitness center A, which was ventilated with a split system. However, fitness centers B (split ventilation system) and C (central ventilation system) also have mean CO_2 concentrations that differ significantly from each other ($p < 0.01$), as shown in Table 2.

Fitness centers A and C both demonstrated CO_2 concentrations significantly above the maximum level recommended by both the Brazilian and French regulatory guidelines. All three fitness centers investigated exhibited CO_2 concentrations significantly above the maximum levels recommended by the European standards (Table 2).

The maximum CO_2 concentration value was obtained in fitness center A, and is approximately seven times greater than the Brazilian and French standard maximum recommended level and ten times greater than the European standard recommended level.

Table 2. CO_2 concentration levels (ppm) in the fitness centers compared to the recommended guidelines from Brazil, France, and Europe.

CO_2 concentration level (ppm)		Fitness Center A	Fitness Center B	Fitness Center C
Mean		3752.13	1000.44	1360.89
Median		3525.50	914.00	1364.00
Standard deviation		1767.98	413.14	309.20
Minimum		597.00	461.00	798.00
Maximum		7533.00	2277.00	2286.00
p-value Brazilian and French standards	1000 ppm	0.00	0.99	0.00
p-value European standard	750 ppm	0.00	0.00	0.00

Legend: ppm: parts per million.

The mean values for human occupation in the fitness centers was 19 people (min. 1, max. 40) in fitness center A, 18 people (min. 5, max. 33) in fitness center B, and 27 people (min. 11, max. 63) in fitness center C, as shown in Figure 1.

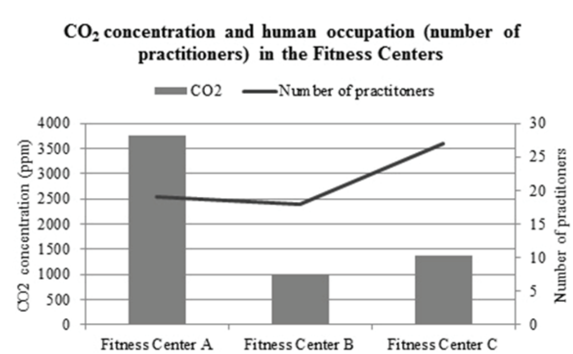

Figure 1. Mean CO_2 concentration and human occupation levels (number of people) in the fitness centers.

It was observed that the mean CO_2 concentrations in the fitness centers were higher in the evening than in the morning or afternoon, and this was also true of the maximum CO_2 concentration values. These results are summarized in Table 3.

Table 3. CO_2 concentrations (ppm) in the fitness centers at different times of day (morning, afternoon, and evening)

	CO_2 concentration (ppm)								
	Fitness Center A			Fitness Center B			Fitness Center C		
	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening
Mean	2612.23	2848.97	5543.53	827.41	562.28	1243.83	1373.98	1070.36	1742.90
Standard deviation	904.38	1132.06	1315.79	177.20	127.29	418.39	224.75	149.92	219.46
Minimum	597	865	2846	574	461	610	987	798	1347
Maximum	3984	4392	7533	1229	833	2227	1872	1452	2286

Legend: ppm: parts per million.

The CO_2 concentration levels were also significantly different ($p < 0.01$) when considering the different physical characteristics and ventilation systems of the fitness centers. Fitness center characteristics of low ceiling height, a split ventilation system, a total area less than 400 m^2, and fewer than 60 machines in the weight room all resulted in higher CO_2 concentration levels, as listed in Table 4.

Table 4. CO_2 concentration levels (ppm) for varying physical characteristics of the fitness centers.

Physical characteristics	CO_2 concentration levels (ppm)					
	$\bar{x}$	±	md	min	max	*p*
Height						=0,00
Low	3752.13	1767.98	3525.50	597	7533	
High	1189.77	403.89	1112	461	2286	
Area						=0,00
Up to 400m²	2597.41	1931.75	1922	461	7533	
ore than 400m²	1360.89	309.20	1364	798	2286	
Type of ventilation system						=0,00
Split System	2597.41	1931.75	1922	461	7533	
Central System	1360.89	309.20	1364	798	2286	
Machines in the weight room						=0,00
Up to 60	2597.41	1931.75	1922	461	7533	
More than 60	1360.89	309.20	1364	798	2286	

Legend: ppm: parts per million; $\bar{x}$: mean; ± : Standard deviation; md: median; min: minimum; max: maximum; p: p-value; m^2: area in square meters.

Discussion

This study presents research and discussion on the issue of air quality and the physical environment in relation to physical exercise at fitness centers. Very few studies have been published on this topic, and to date there have been no studies at all of this nature conducted in Brazil.

CO_2 concentrations are significantly above recommended guidelines

This study indicates fitness centers have high indoor CO_2 concentrations that exceed the limits recommended by Brazilian, French, and European regulatory guidelines. In sporting facilities, a relatively low CO_2 concentration level and high rate of ventilation with outdoor air indicate an efficient ventilation of the environment (Alves et al., 2013), and it is recommended that attention be similarly focused on factors related to air quality in fitness centers.

Regarding the use of recommended values of CO_2 concentration as indicators of adequate ventilation, the literature is somewhat divided. In Brazil, a lack of epidemiological data has resulted in a recommended level that has been maintained at 1000 ppm (Brasil, 2003). As in Brazil, the French regulations for non-residential buildings also indicate a guideline CO_2 concentration level of 1000 ppm. The European standard is more stringent and recommends a maximum CO_2 concentration level of 750 ppm. According to the Brazilian and French regulatory guidelines, CO_2 concentration peaks above 1000 ppm in the breathing zone indicate inadequate ventilation. On the other hand, concentrations below 1000 ppm generally indicate that the ventilation is adequate to dilute contamination generated in the environment (Brasil, 2003). However, complying with these guidelines does not always ensure that the ventilation is sufficient to remove air pollutants from other indoor sources (Apte, Fisk, & Daisey, 2000), including dust, chemicals, microorganisms, or other particles and pollutants suspended in the air (Rios & Boechat, 2011).

The CO_2 levels observed in the fitness centers in this study were ten times greater than the European guidelines and seven times greater than the Brazilian and French guidelines at various times, necessitating an urgency of concern regarding several aspects of the environment, indoor air quality, and potential risks to the health of the patrons. There may be resulting risks to respiratory health, a decreased perception of environmental comfort on behalf of the occupants, as well as risks that can arise from the association of CO_2 concentrations with other parameters such as pollution risk and the presence of pathogenic microorganisms (Rudnick & Milton, 2003).

Health risks

According to the American Conference of Governmental Industrial Hygienists Bioaerosol Committee [ACGIH] (1991), while exposure to the CO_2 levels that are commonly found in indoor environments (350–2500 ppm) is not considered a direct cause of adverse health effects, there are some concerns about direct and measurable impacts on human health. It is known, for example, that decreased air exchange with outdoor environments can lead to drowsiness and loss of productivity in healthy individuals (Schirmer, Szymanski, & Gauer, 2009). In this study, performance during physical exercise could be affected by the CO_2 concentration (Ramos et al., 2014). However, Vercruyssen et al. (2007) have shown that the inhalation of air with very high CO_2 concentrations (greater than 25,800 ppm) has no observable effect on psychomotor performance. The effect of CO_2 concentration on physical performance still requires additional research and more consistent evidence.

According to Pegas et al. (2011) and Chatzidiakou, Mumovic and Summerfield (2015), CO_2 concentration levels above 1000 ppm are typically considered indicative of inefficient ventilation for the dispersal of body odors. This becomes important in environments designed for physical activity and sports, in which there can be excessive sweating. Moreover, high CO_2 concentration levels can indicate the presence of other pollutants (Ramalho et al., 2015) as a result of inefficient ventilation, and this can cause user complaints (Illinois Department of Public Health [IDPH], 2011). A polluted environment can also cause health problems in the personal trainers and other staff working in fitness centers (Barreira & Carvalho, 2007).

A study conducted at two sporting facilities in Spain by Alves et al. (2013) found low CO_2 concentration levels (413 and 468 ppm) and high rates of exchange with outdoor air, leading to a conclusion that there was effective ventilation in both facilities. On the other hand, an investigation into 11 fitness centers in Portugal (Ramos et al., 2015), found high CO_2 concentration levels, with an average concentration of 1032 ppm and a maximum observed concentration of 2899 ppm. These sporting facilities had relatively low ventilation rates (Ramos et al., 2014). These results can influence the perception of comfort of the practitioners in these facilities. In total, 54% of the fitness centers exceeded the maximum CO_2 concentration of 1161 ppm recommended by the Portuguese Legislature (2013) (Ramos et al., 2015). As a result, an increasing number of fitness centers in Portugal give an appearance of providing poor quality for the environmental comfort of their customers (Barreira & Carvalho, 2007).

Physical characteristics of the fitness centers

The fitness centers that have a total area of less than 400 m^2, low ceiling height, and a split system of ventilation demonstrate higher CO_2 concentrations. This is in agreement with Tan and Mulyono (2010), who found that the height and area of sporting facilities can affect indoor air quality. The CO_2 concentration is a function of site occupancy, thus smaller sites and greater accumulation of people are expected to result in higher CO_2 concentrations if there is no indoor air replenishment. This can occur in environments that utilize split systems of ventilation, as this system only provides circulation of ambient air without exchange with the outdoor air (Graudenz, Oliveira, Tribess, Mendes, Latorre, & Kalil, 2005; Tan & Mulyono, 2010).

Furthermore, according to Pereira et al. (2009), split systems do not have adequate filtration systems for the removal of contaminant particles. In addition, the air circulating in the indoor environment is turbulent and directionless, which can increase discomfort and exacerbate the dispersion of internal contamination.

Fitness center B had a height of 4 m and a split system of ventilation, and it was the location with the lowest CO_2 concentration. The split system of ventilation in this fitness center is located at a height of 2 m. Consequently, the warmest air goes to upper part of the room, and most of the CO_2 generated in this environment also migrates to that region. Because of the high ceiling height at this fitness center, most of the CO_2 generated internally pools in the upper part of the room, above the height of the HVAC equipment. As a result, in the breathing zone of this fitness center, the observed CO_2 concentrations are low, creating a false impression of good ventilation quality.

Fitness center C, although having a high ceiling height and central ventilation system, also had a high CO_2 concentration. During data collection, it was observed that the inlet grille for external air intake was closed. In this case, there can be is no exchange with outdoor air inside the fitness center, resulting in elevated CO_2 concentrations indoors.

Studies have shown a positive relationship between human occupation rates and the level of pollutants such as CO_2 during indoor physical activities (Ramos et al., 2015; Buonanno, Fuoco, Marini & Stabile, 2012). Furthermore, there is a relationship between exercise intensity and CO_2 concentration (Ramos et al., 2014; Ramos et al., 2015), where the CO_2 level is influenced by the metabolic activity of practitioners of physical exercise. However, this study did not perform analyses to support a discussion of these relationships. The study is limited by the number of fitness centers in the sample size. It is suggested that future studies investigate air quality in a greater number of establishments in order to address factors related to the environmental comfort of practitioners.

Conclusion

CO_2 concentrations recorded in fitness centers were significantly higher than the maximum recommended levels, reaching as high as ten times the recommended standard. These results suggest inefficient ventilation in these fitness centers. Furthermore, these CO_2 concentration levels can impair the air quality and increase risks to the health of practitioners. Given the focus on physical exercise, it is important to take care with the air quality of institutions for physical exercise and sports.

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