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Estimating the inhaled dose of pollutants during indoor physical activity

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HIGHLIGHTS

- Exposure to air pollutants is enhanced during physical activity.
- The dose assessment of pollutants is part of the health risk assessment.
- This work conducted an assessment on minute ventilation during fitness classes.
- Aerobic classes induces 2.1× more inhaled dose than holistic classes.
- People will obtain the best gains from exercise if exposure to pollutants is reduced.

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ABSTRACT

Background: It is undeniable that many benefits come from physical activity. People exercise in fitness centers to improve their health and well-being, prevent disease and to increase physical attractiveness. However, these facilities join conditions that cause poor indoor air quality. Moreover, increased inhalation rates during exercise have influence on inhaled doses of air pollution.
Objectives: This study aims to calculate the inhaled dose of air pollutants during exercise, by estimating minute ventilation of participants and measuring air pollutant concentrations in fitness centers.
Methods: Firstly, the 20 participants performed an incremental test on a treadmill, where heart rate and minute ventilation were measured simultaneously to develop individual exponential regression equations. Secondly, heart rate was measured during fitness classes and minute ventilation was estimated based on the calculated regression coefficients. Finally, the inhaled dose of air pollutants was calculated using the estimated minute ventilation and the concentrations of the pollutants measured in a monitoring program performed in 63 fitness classes.
Results: Estimated inhaled doses were higher in aerobic classes than in holistic classes. The main difference was registered for PM_{10} inhaled dose that presented an average ratio between aerobic and holistic classes greater than four. Minute ventilation and PM_{10} concentrations in aerobic classes were, on average, 2.0 times higher than in holistic classes. Results showed that inhalation of pollutants is increased during heavy exercise, demonstrating the need to maintain high indoor air quality in fitness centers.
Conclusions: This study illustrates the importance of inclusion minute ventilation data when comparing inhaled doses of air pollution between different population groups. This work has estimated for the first time the minute ventilation for different fitness classes. Also constitutes an important contribution for the assessment of inhaled dose in future studies to be performed in fitness centers.

1. Introduction

Approximately 3.2 million deaths each year are attributable to insufficient physical activity and it is the fourth leading risk factor for death worldwide (WHO, 2014). The benefits that come from physical activity are indubitable (Warburton et al., 2006) and contribute to improve people's health, reducing cardiovascular diseases (Myers, 2003; Patel et al., 2013) and diabetes (Brown et al., 2014; Weisser, 2014), preventing several types of cancer and recovering from it (Foucaut et al., 2014; Keimling et al., 2014; Behrens et al., 2014; Gotte et al., 2013; Gonçalves et al., 2014; Buffart et al., 2014), improving musculoskeletal status and disability (Laskowski and Lexell, 2012) and finally potentiating physical attractiveness, well-being (Duda et al., 2014)

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and social experiences (Pila et al., 2014). The rates of physical activity are different across countries and regions, gender, age and socioeconomic status. According to the Eurobarometer Sport and Physical Activity Report (2013), citizens in the northern part of the EU are more physically active than the southern, with the lowest levels of participation found clustered in the southern EU Member States. Men are more likely to exercise or play sports than women, with the amount of regular activity tending to decrease with age.

The practice of sport in fitness centers in 2009 registered a slight increase in the number of memberships of health or fitness centers (European Comission, 2014). Fitness centers join specific characteristics that can affect indoor air quality (IAQ) and trained or recreational athletes can be at risk when they exercise in polluted environments due the fact that 1) the increases of the minute ventilation increases proportionally to the quantity of inhaled pollutants; 2) most of the air is inhaled through the mouth, bypassing the normal nasal mechanisms for filtration of large particles and 3) the increased airflow velocity carries gaseous pollutants deeper into the respiratory tract (Carlisle and Sharp, 2001). An IAQ monitoring program performed in eleven fitness centers from Lisbon, Portugal, indicated concerning levels of volatile organic compounds (VOC), formaldehyde (CH_2O), carbon dioxide (CO_2) and particulate matter (PM) (Ramos et al., 2014). Moreover, toxigenic fungal species were found present within the same fitness centers (Ramos et al., in press). PM has also been identified as a concerning pollutant in fitness centers by Braniš and Safranek (2011) and Buonanno et al. (2013).

Data on IAQ in fitness centers demonstrate the importance of studying exposure to pollutants during physical activity in order to minimize adverse health effects and potentiate the benefits of physical activity. Moreover, there is an increasing number of studies on exposure to air pollutants in different indoor air spaces: elderly care centers (Almeida-Silva et al., 2014a, 2014b; Viegas et al., 2014), offices (Almeida et al., 2013), schools (Pegas et al., 2010; Canha et al., 2011, 2014) and fitness centers (Ramos et al., 2014). However, only few of them have taken into account that sport practitioners have an increased minute ventilation (V̇E) compared to elders, office workers or children influencing their inhaled dose of air pollutants (Almeida-Silva et al., 2015). For increased health benefits, adults should practice moderate-intensity aerobic physical activity to 300 min/week (WHO, 2010). This represents 5 h/week and with this information, the time spent during exercise reveals great importance to the relative daily dose, due to the increased V̇E in this activity than in others that take more time (e.g., sleep) (Dons et al., 2011).

The study of the interaction between person and pollutant involves several steps. The inhaled dose is one of the principal steps in the chain of events since dose received by an individual directly influences the impacts on health. This work joined environmental researchers and exercise physiologists to assess the inhaled dose of pollutants during fitness center's classes.

2. Methods

The inhalation dose of pollutants during the fitness classes was estimated by using the methodology described in Fig. 1.

2.1. Determination of V̇E during fitness classes

Since V̇E has never been measured before for fitness class users, this work estimated V̇E for aerobic and holistic classes that represent the majority of the programs offered in fitness centers. V̇E is difficult to measure in field studies due to some constraints such as discomfort for the user and the need for an elevated number of instruments to perform the evaluation of a representative number of individuals. However, V̇E can be estimated by measuring HR in fitness classes because HR is easily measured and is a good predictor of V̇E (Mermier et al., 1993; Zuurbier et al., 2009). Once HR is mainly influenced by oxygen consumption and the correlation between oxygen consumption and V̇E is high, HR and V̇E are expected to be strongly associated.

2.1.1. Studied population

Ten men and ten women participated in this study and signed a free and informed agreement. A questionnaire was applied to the participants about their physical status and healthy behaviors (smoking status, hours of physical activity per week, cardiac and respiratory diseases, orthopedic problems). On test days, the subjects were instructed to report to the laboratory or the fitness center in a rested state, having completed no strenuous exercise or consumed alcohol within the previous 24 h, and having abstained from food and caffeine for the preceding 3 h.

Table 1 presents the descriptive statistics of the studied population. The age of the volunteers varied between 18 and 38 years old, representative of principal users of fitness centers. All the subjects

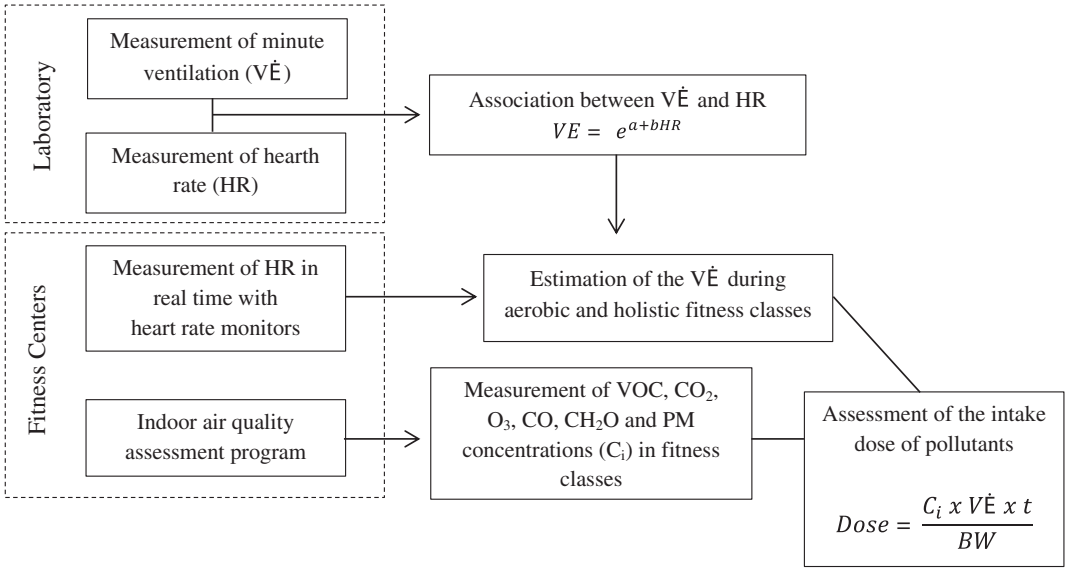

Fig. 1. Diagram of the methodology (BW — body mass in kg; t — duration of the fitness class).