



## Review

## Indoor air quality of environments used for physical exercise and sports practice: Systematic review



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## ABSTRACT

**Background:** Systematic reviews have the potential to contribute substantially to environmental health and risk assessment.

**Objective:** This study aimed to investigate indoor air quality of environments used for physical exercise and sports practice through a systematic review.

**Methods:** The systematic review followed the PRISMA guidelines and was recorded in the PROSPERO registry (CRD42016036057). The search was performed using the SciELO, Science Direct, Scopus, LILACS, MEDLINE via PubMed, and SPORTDiscus databases, from their inception through April 2017. The search terms used in the databases were {air pollution} OR {air pollutants} OR {air quality} AND {"physical exercise" OR "physical activity" OR "sport"}. The results of selected studies were divided into 5 categories for analysis: monitoring of air quality in the environment according to international guidelines, indoor-to-outdoor ratio (I/O), air quality during physical exercise, impact of air quality on health, and interventions to improve indoor air quality.

**Results:** Among 1281 studies screened, 34 satisfied the inclusion criteria. The monitoring of pollutants was conducted in 20 studies. CO and NO<sub>2</sub> were the most investigated pollutants, and guidelines were discussed in most studies. The I/O ratio was investigated in 12 studies, of which 9 showed a higher concentration of some pollutants in indoor rather than outdoor environments. Among the 34 studies selected, only 7 investigated the impact of indoor air pollution on human health. The population in most of these studies consisted of hockey players.

**Conclusion:** Most studies conducted monitoring of pollutants in indoor environments used for physical exercise and sports practice. The earliest studies were conducted in ice skating rinks and the most recent evaluated gymnasiums, fitness centers, and sports centers. The CO, particulate matter, and NO<sub>2</sub> concentrations were the most investigated and have the longest history of investigation. These pollutants were within the limits established by guidelines in most studies. Studies that examined the association between air quality documented the adverse effects of pollution. There is a need for more studies focused on the relationship between pollution and health.

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## Contents

1. Introduction .....	578
2. Methods .....	578
2.1. Search strategy .....	578
2.2. Eligibility criteria .....	579
2.3. Study selection and data extraction .....	579
3. Results .....	579
3.1. Methodological analysis .....	579
3.1.1. Study design .....	579

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3.1.2.	Place of research .....	579
3.1.3.	Pollutants .....	579
3.1.4.	Duration of pollutant monitoring .....	579
3.2.	Analysis of results from the studies .....	579
4.	Discussion .....	579
4.1.	Monitoring of IAQ according to guidelines .....	581
4.2.	Relationship between indoor and outdoor environmental pollutants .....	582
4.3.	Interventions to improve IAQ .....	582
4.4.	IAQ during physical exercise .....	582
4.5.	Impact of air quality on health .....	584
4.6.	Limitations .....	585
5.	Conclusion .....	585
	Acknowledgements .....	585
	References .....	585

## 1. Introduction

Air pollution is the greatest environmental risk to health worldwide, accounting for 1 in 8 deaths in 2012 (WHO, 2016). The effect of air pollution on human health in both indoor and outdoor environments is a reason for concern due to the high exposure risk, even at low pollutant concentrations (Kim et al., 2015). Accordingly, researchers have shown increasing interest in indoor air quality (IAQ) due to the time spent in indoor environments, which is as much as 90% of the day (Andrade et al., 2017a,b; Castro et al., 2015; Godoi et al., 2009).

Research on IAQ increased in the 1970s due to awareness of decreased air exchange with the outdoor environment (Nagel Schirmer et al., 2011). The prolonged duration of exposure to indoor pollution could be up to 5 times greater than that for outdoor pollution (Buonanno et al., 2012), with significant risk to human health.

Studies on air pollution have been performed in environments such as homes, hospitals, offices, and schools (Buonanno et al., 2013; Pereira et al., 2017; Fuoco et al., 2015; Wells et al., 2015; Maula et al., 2017). These environments have similar characteristics influencing air quality, such as location, size, type of ventilation, and materials used in construction and maintenance (Ramos et al., 2014). The unique features that make such environments of interest to researchers are the human presence and type of activity in the indoor environment (Ramos et al., 2014).

Sports and physical exercise are characterized by physical, psychological, and performance aspects (Brandt et al., 2017; Andrade et al., 2017a,b; Andrade et al., 2016), and are often performed in indoor environments. The metabolic response to physical exercise exposes the body to the greatest amount of pollutants, since the increase in respiratory ventilation per minute during exercise results in the inhalation of a greater amount of air and consequently of pollutants present in the air (Carlisle and Sharp, 2001). During exercise, air tends to be inhaled through the mouth, rather than passing through the nasal particle-filtering apparatus. The increase in air flow velocity results in the transport of pollutants into the deepest part of the respiratory system, increasing the risk to human health (Carlisle and Sharp, 2001). In fact, those performing physical exercise in polluted environments may be placing their health at risk (Ramos et al., 2014).

The international literature has produced little knowledge about the implications of air pollutants on health (Adar et al., 2014), resulting in a critical gap in the knowledge required for development of policies to control and reduce these risks to human health. Systematic reviews have the potential to contribute substantially to environmental health and risk assessment (Sheehan and Lam,

2015). Although this type of study is relatively new to the field of environmental sciences, reviews have contributed to the use of scientific evidence in policy-making (Sheehan et al., 2016).

Therefore, it is important to analyze the impact of air quality on human health. This study aims to investigate the IAQ of environments used for physical exercise and sports practice, through a systematic review of the literature.

## 2. Methods

This systematic review was conducted according to the recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) (Moher et al., 2015). This review was recorded in the PROSPERO registry (CRD42016036057), prior to completion of formal screening of search results based on eligibility criteria (Booth et al., 2012). One of the main goals of PROSPERO is to make the intent of systematic reviews known before they are conducted in order to reduce unplanned duplication (Moher et al., 2014).

### 2.1. Search strategy

Representing a significant part of the world's scientific production, the search for studies was performed using the following electronic databases: Scientific Electronic Library Online, SciELO ( $\cong$  1156 periodicals and 479,891 articles), Science Direct ( $\cong$  2500 periodicals and 13,397,561 articles), SCOPUS (21,000 titles from 5000 international publishers), Literatura Latino-Americana e do Caribe em Ciências da Saúde, LILACS ( $\cong$  877 periodicals and 551,904 articles), Medical Literature Analysis and Retrieval System Online, MEDLINE ( $\cong$  5600 periodicals and 21,000,000 articles) via PubMed ( $\cong$  4916 periodicals and 3,300,000 articles), and SPORTDiscus ( $\cong$  670 periodicals). These databases were selected due to the significance and relevance on the field of health, sports and environmental sciences, since the most important journals of these areas are indexed in these databases.

We searched these databases from their inception through April 2017 and the last search was conducted on April 13th, 2017. The search terms used in the databases were {"air pollution" OR "air pollutants" OR "air quality"} AND {"physical exercise" OR "physical activity" OR "sport"} (Table 1). This strategy was permuted in all databases, with an integrated search in the title, abstract, and subject fields.

In the Science Direct database the search was realized in the advanced search with the search terms, selecting the abstract, title, keywords field and all years of publication.

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