

Return to Play? Increased Risk of COVID-19 Transmission in Indoor Ice Rinks

The air quality inside ice arenas has been a topic of study for many years, motivated by the impact of indoor use of ice resurfacing equipment, notably Zambonis. These gasoline- or propane-powered vehicles release air pollutants, including carbon monoxide, nitrogen dioxides, volatile organic compounds and particulate matter, which are known to cause adverse health effects (Brauer et al. 1994, Lee et al. 1994, Spengler et al. 1978, Yoon et al. 1996, Salonen et al. 2020, Rundell et al. 2003). Challenges in efficiently ventilating these unique indoor spaces can lead to elevated levels of these air pollutants. The cool air near the ice pad and the warmer air aloft create a thermal inversion that can restrict air movement/moving from the ice pad to other areas in the arena. Air flows are further limited in indoor ice arenas by boards and plexiglass shielding that can extend 9 to 12 feet above the ice surface (Omri et al. 2010).

A recent study visualized this stagnation of air by operating a smoke generator on the ice surface (Toomla et al. 2019). After about two minutes, the smoke settled at about 10 feet above the ice pad – see Figure 1. This demonstration is supported by computational fluid dynamic (CFD) models of air velocity and temperature above the ice pad, and has also highlighted the accumulation of air pollutants in the breathing zone of individuals skating on the ice (Yang et al. 2000). In addition to health concerns about elevated exposure to combustion-related emissions, the restricted air flow in indoor ice arenas also suggests these spaces may pose an increased risk during the COVID-19 pandemic.



Figure 1. Smoke released from a smoke generator has been shown to settle about 10 ft above the ice surface. Adapted from Toomla et al. 2019.

COVID-19 is an infectious disease caused by a coronavirus identified in late 2019, the so-called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). A person infected with COVID-19 releases viral material in the form of ballistic droplets when they cough or shout, as well as smaller-sized aerosols through other respiratory activities such as breathing, speaking or singing (Asadi et al. 2020). Ballistic

droplets tend to settle quickly, presenting a risk of transmission in situations with proximal contact (<6 feet). In contrast, aerosols (sized <100 μm) can remain airborne for extended periods, creating a risk of far-field transmission of SARS-CoV-2. Poorly ventilated enclosed spaces, such as indoor ice arenas, can lead to increased exposure to virus-laden aerosols.

While dynamics and spatial distribution of SARS-CoV-2 aerosols have not been studied in indoor ice arenas due to safety-related state restrictions on use, past studies have assessed other similarly sized bioaerosols. Bacteria of human origin were detected in aerosols collected at breathing height above the ice in an indoor arena (Brągoszewska et al. 2020). Interestingly, in this study, operation of the building's heating, ventilation and air conditioning (HVAC) system (8,450 cu. ft. per min. [CFM] outdoor air [OA]) was only found to lower airborne levels of bacteria by 25% compared to periods with no mechanical ventilation.

HVAC systems in indoor ice arenas serve to bring outdoor air into the space, diluting airborne contaminants and maintaining indoor air quality requirements. Minimum ventilation in sports arenas set by the American Society of Heating, Refrigeration and Air-conditioning Engineers' (ASHRAE) Ventilation for Acceptable Indoor Air Quality, Standard 62.1-2007 is 0.3 CFM/ft² ice. Based on these standards, an NHL-sized rink (16,327 ft²) requires 16,330 CFM OA. This high outdoor supply air has been experimentally shown to achieve complete mixing in the upper zone of the arena and the spectator stands around the ice; however, the thermal inversion over the ice pad reduced air exchange efficiency in this area to 27% (Toomla et al. 2019).

To evaluate the influence of poor ventilation on the transmission risk of SARS-CoV-2 while skating in indoor ice arenas, the probability of infection for various scenarios was modeled exploring the impact of: 1) HVAC supply air flow, 2) the number of COVID-19 infected people on the ice, and 3) mask use. A [Wells-Riley model](#) was used to assess airborne transmission; this model does not account for disease transmission through ballistic droplets or fomites. The limited air mixing over the ice pad was reflected in modeling results suggesting minimal differences in the probability of infection in an arena following ASHRAE-recommended ventilation standards (20,000 CFM; 1.1 air changes per hour at ice level) compared to space with a reduced outdoor supply air (2,500 CFM; 0.2 air changes per hour) — see Figure 2. Modeled HVAC operation levels corresponded to 1.1 air changes per hour (ACH) at ice level for the scenario with higher supply air and 0.2 ACH for the reduced supply air scenario, assuming an NHL-sized rink. Ice rinks are commonly shared by two teams, with potentially 50 people on the ice. At a 7% COVID-19 test-positivity rate (as in Connecticut in early January 2021), four COVID-19 infected people could be skating at a given time. In both high- and low-HVAC ventilation scenarios, the probability of infection increased 2.4 to 3.5 times when comparing one versus five infected skaters on the ice. The importance of wearing a mask is reinforced with these modeling estimates – the probability of infection was found to be 1.5 to 2.5 greater for people not wearing a cloth mask compared to skaters assumed to wearing a mask.

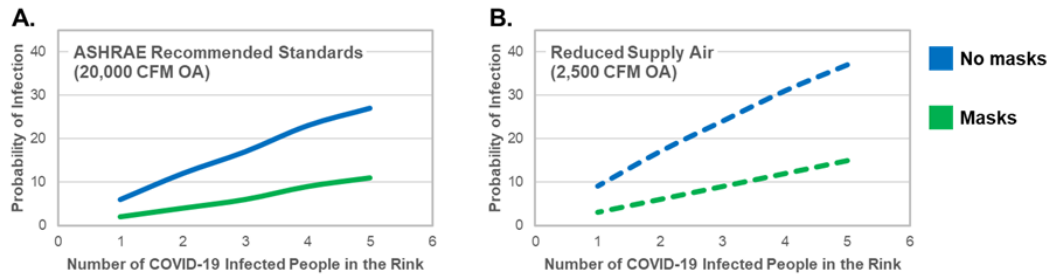


Figure 2. Probability of COVID-19 infection after 60 minutes of skating with or without a mask in an indoor ice rink operated at 20,000 CFM (A) and 2,500 CFM (B) HVAC outdoor air supply.

The elevated levels of combustion-derived air pollutants in indoor ice arenas have been suggested to compound the risk of COVID-19 infection (Frontera et al. 2020). Fine particulate matter and nitrogen dioxide can upregulate angiotensin-converting enzyme-2 (ACE2) receptors (Borro et al. 2020), to which SARS-CoV-2 binds. Thus, increased ACE2 receptor expression due to poor indoor air quality has been suggested to impact the severity of infection (Paital et al. 2020).

Other environmental conditions in indoor ice arenas (Omri et al. 2010), including temperature (55-65°F) and humidity (33-47%) that are designed to preserve the integrity of the ice surface, may promote stability of SARS-CoV-2 aerosols (Dabisch et al. 2021).

Given the available research investigating indoor ice arenas and the dynamics and survival of SARS-CoV-2 in aerosols suggest:

- Poor air quality and air movement/mixing conditions can lead to elevated levels of airborne contaminants (combustion-related emissions, bioaerosols) at the breathing height of skaters on the ice pad;
- Temperature and humidity conditions inside ice arenas are within the range of conditions that may increase the survival of SARS-CoV-2 in aerosol;
- Co-exposure to elevated levels of air pollutants, such as fine particulate matter and nitrogen dioxide, may exacerbate the severity of COVID infection;
- Highly aerobic activity like skating will enhance respiration rate, increasing the release of potentially infectious aerosol if COVID-19 infected individuals are on the ice; and,
- Highly aerobic activity will similarly enhance the risk of SARS-CoV-2 transmission through increase inhalation of airborne contaminants.

It is reasonable to suspect that the use of indoor ice arenas will increase the exposure of skaters to SARS-CoV-2 aerosols. Athletic activities occurring inside ice arenas may pose an increased risk of COVID-19 transmission compared to athletic activities occurring in other indoor and outdoor environments.

Please email Krystal Pollitt with questions.

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