

Emerging Evidence on COVID-19

Evidence Brief of SARS-CoV-2 Risks in Arenas

Introduction

What evidence exists for the risk of SARS-CoV-2 transmission in arenas, on and off the ice surface?

COVID-19 outbreaks related to arenas and ice sports have highlighted the need to understand how transmission is occurring and what environmental and behavioural factors may be altered to lower the risk of transmission. Professional and recreational hockey, along with other indoor ice surface sports such as curling, ringette, skating and sledge hockey exposures were considered relevant for this evidence brief. Evidence on transmission risks in ice arenas and literature specific to COVID-19 for sport or recreational participants, coaches, spectators, and arena staff was collected. Activities in different sub-environments (e.g., use of the lobby, dressing rooms and hallways before and after on-ice activities, the spectator areas and the on-ice activities) were considered when reviewing the evidence. Reviews on the effect of temperature and humidity on transmission of SARS-CoV-2 were also included in this brief as indirect evidence of SARS-CoV-2 survival under cold conditions. The use of combustion engine ice resurfacing equipment has led to indoor ice facility air quality concerns in the past, but no connection of this research to COVID-19 risks has been documented, so it not considered. This brief summarizes review and primary literature available up to February 12, 2021.

Key Points

- This review included 13 publications: two outbreak investigations related to ice hockey (1, 2), and two related to curling bonspiels (3, 4). Two cross-sectional studies included observational data from August to October 2020 looking at risk factors for COVID-19 associated with other recreational sports in the USA (5, 6). Three reviews summarize the literature on SARS-Cov-2 under cold or low humidity environments such as those found in the arena.

Arena/Ice Sports:

- Hockey provides favourable conditions for SARS-CoV-2 transmission due to:
 - Heavy breathing on ice and on the bench due to high intensity physical activity;
 - Close proximity of players, coaches;
 - Indoor gathering;
 - Dry, cold air of the arena; and
 - Segregated air mass due to ~10 foot barriers around the ice leading to poor air circulation. (1, 2, 7).

- An investigation of a June 2020 outbreak among recreational men's hockey teams theorized that one presymptomatic individual lead to 14 symptomatic adults (12 confirmed, 2 not tested), 13 players across both teams and 1 arena employee (2). No PHMs were reported to have been in place.
- An outbreak within the Finnish U-20 hockey league was investigated and speculated to have likely been caused by one asymptomatic player, resulting in transmission to two opposing teams and tertiary transmission to senior league teams for a total of 49 confirmed COVID-19 infections (1). After the outbreak, the league implemented measures to minimize the risk COVID-19 transmission, including associating with only one team.
- Two bonspiel outbreak investigations noted social gatherings with few precautions for a prolonged period of time (3, 4). Thus, transmission risk cannot be attributed to the sport or the venue.
- When resuming both recreational and professional hockey and other indoor ice activities, strategies for reducing transmission risk include: limiting the number of individuals in the arena, lessening time in the arena, screening of individuals and increasing sanitation, cohorting players, minimizing exposure time and sharing of equipment, using masks and maintaining physical distancing (5-9).

Other Sports:

- Evidence from two cross-sectional studies describes lower risk of COVID-19 among outdoor sports compared to indoor sports, non-contact sports compared to contact sports and that for some indoor sports, wearing a mask had a significant protective association (5, 6).

Indirect Evidence:

- Evidence of the survival and transmission potential of SARS-CoV-2 in cold and low humidity level environments has not been studied well in the literature. However recent reviews that looked at experimental evidence consistently indicate lower temperatures and humidity are favorable for SARS-CoV-2 survival. Similarly, studies of weather and environment consistently indicate higher SARS-CoV-2 transmission in areas with low temperatures (0-17°C) and a significant interaction between temperature and humidity, but not humidity on its own (10-16).

Overview of the Evidence

Thirteen articles were included in this brief, six primary literature articles that provide descriptions of outbreaks related to sports, four guidance documents for resumption of hockey (two for professional hockey leagues, one for Canadian hockey and one for youth sports) and three reviews that cover transmission of SARS-CoV-2 or survival in cold temperatures. Four outbreaks, two non-professional hockey and two curling bonspiels and two cross-sectional analyses of non-arena based sports at high school and youth soccer were included. No evidence was found related to other indoor ice activities, such as skating, sledge hockey or ringette.

Outbreak investigations are retrospective collections of evidence and findings are at risk of several biases; and all identified uncertainty about where transmission occurred. Some cross-sectional studies were included, which provide a point in time dataset of a population, however they can only establish associations and not causation between an exposure and an outcome. A range of review types were included, and systematic reviews were rated by the AMSTAR-2 tool. Narrative literature reviews were considered low quality due to a high risk of bias. The limitations of the evidence include a very small number of articles in the literature related to arenas, despite many jurisdictions reporting cases or outbreaks traced to hockey teams or curling (e.g., [CBC news](#) January 16, 2021). The nature of sports makes it difficult to establish with certainty where transmission occurred, as teammates often spend time together for practice, training, game travel, meals and recreational activities. Tournaments can add more mixing opportunities and exposures between teams, as well. Lastly, all of the outbreaks currently in the literature occurred early in the pandemic, when mask use and other public health measures were not widely used.

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INDOOR ICE SPORT OUTBREAKS

Table 1: Transmission Linked to Indoor Ice Sports and Other Sports (n=6)

STUDY	OUTBREAK DESCRIPTION	KEY OUTCOMES
Hockey (n=2)		
Atrubin (2020) (2) Outbreak investigation United States Jun 2020	2 Teams (A & B) played a recreational hockey game June 16, 2020 (day 0) in Tampa Bay, Florida. Each team had 11 male members, aged 19-53 years. By June 21 (day 5), 15 individuals were symptomatic with suspected COVID-19. <ul style="list-style-type: none"> • Index patient – Team A player, who was symptomatic 1 day after the game; and tested positive on day 3. • Secondary cases – 14 symptomatic adults (12 confirmed, 2 not tested); 13 of the game players and 1 employee at the arena. • Asymptomatic contacts of the game were not tested. 	Subsequent cases: <ul style="list-style-type: none"> • 8 of 10 teammates of the index case became symptomatic; • 5 of 11 players of opposing team became symptomatic; • 1 arena employee symptomatic; and • Asymptomatic contacts not tested: players (8 of 21), 2 referees and 1 spectator. • PHMs were not reported including wearing masks. • Game play was 60 minutes. • Locker rooms used, one for each team, 20 minutes before and after game.

		<ul style="list-style-type: none"> • Transmission opportunity existed only at the arena, no other contact the week prior. <p>Authors note that hockey provides favourable conditions for SARS-CoV-2 transmission:</p> <ul style="list-style-type: none"> • Heavy breathing on ice and on the bench due to high intensity physical activity; • Close proximity of players; • Indoor gathering; and • Segregated air mass due to ~10 foot barriers around the ice.
<p><u>Kuituen (2021) (1)</u></p> <p>Outbreak investigation</p> <p>Finland</p> <p>Sep 2020</p>	<p>This descriptive report covers transmission of SARS-CoV-2 in a Finnish U-20 hockey league.</p> <p>Team A played team B Sept 4, 2020 (day 0) and team C Sept 5, 2020 (day 1). Some players on all 3 teams also train with senior teams.</p> <p>An asymptomatic player was the index case, and 49 secondary and tertiary cases were detected in 5 teams and 6 teams were quarantined (U-20 A, B and C and Senior A, B and C).</p> <ul style="list-style-type: none"> • Index case – assumed to be a Team A player who was asymptomatic but infective on day 0. (Given there was a high number of asymptomatic positive test results on day 3 post the first game, the index case was not identified.) • Secondary cases (U-20 league): TEAM A - 3 players symptomatic on day 2 and tested positive. Team A all tested day 3 (28 players + staff) with 22 positive players. Team A spent 10h on a bus together travelling to and from their games. 	<p>An asymptomatic hockey player is hypothesized to have been the source of the outbreak that resulted in 49 confirmed COVID-19 infections during a 16-day follow-up.</p> <p>Precautions employed in league:</p> <ul style="list-style-type: none"> - No guidance on face coverings (masks were not worn by players); - Teams did not shake hands in games; and - Spectators were limited so social distancing could be maintained. <p>Transmission within a team may have occurred through travel on the team bus, the locker room or other common team gathering, transmission to team B and C players was determined to have most likely occurred during game play.</p> <p>Multiple close contacts and heavy breathing from high intensity activity during the game are identified as risks for on-ice transmission. As well, the dry, cold air of the arena is suggested to increase the risk of aerosolization of expelled SARS-CoV-2 droplets.</p>

	<p>TEAM B - 3 players tested positive on day 5; 11 more cases subsequently detected.</p> <p>TEAM C – 6 players test positive day 6 (exposure to team A on day 1); 10 more cases subsequently detected.</p> <ul style="list-style-type: none"> • Tertiary cases (senior league): <p>TEAM A – no detected cases.</p> <p>TEAM B – 2 players tested positive.</p> <p>TEAM C – 1 player tested positive.</p>	<p>This outbreak resulted in a change in the Finnish leagues, disallowing U-20 players to train or play with more than 1 team.</p> <p>Bubbles and continuous testing used in professional level sports are not feasible for amateur and youth hockey.</p> <p>A limitation of this investigation is that it is based on publically available data and authors did not interview the players or have access to their health records. This means that the index case was not identified, but assumed to be an asymptomatic player and the likely sequence of transmission is unknown (i.e., how many people were likely infected during the game vs. by their infected teammates at a later date).</p>
<p>Curling (n=2)</p>		
<p><u>Burak (2021)</u> (3)</p> <p>Outbreak investigation</p> <p>Alberta, Canada</p> <p>Mar 2020</p>	<p>A curling bonspiel in Edmonton Mar 11-14, 2020 was attended by 73 individuals. This descriptive study is based on interviews of the attendees between Apr 17 and May 5. In addition to the self-reported symptoms and test results, samples were collected for serology testing from 62 of 73 participants. 58 of the 73 participants in the bonspiel were physicians, all were healthcare workers.</p> <p>40 curlers tested positive for SARS-CoV-2, and 30 of these individuals had a positive serology result within 222 days after the bonspiel. 16 others who reported symptoms tested negative or were not tested (14 of these are reported as probable cases) and 7 of the probable cases had positive serology results. Asymptomatic attendees were not tested. Serology testing was negative for 12 and positive in 1 of the 17 asymptomatic curlers. 35 suspected cases of secondary</p>	<p>The curling event and related social activities led to a 74% attack rate for COVID-19 in participants.</p> <p>No index case was identified, but 10 individuals reported minor nonspecific symptoms at the time of the bonspiel.</p> <p>The study does not determine the activities that resulted in transmission, but does hypothesize shared meals as the source due to surveys of participants' activities.</p>

	transmission were reported by participants due to symptoms or positive tests of household contacts after the event.	
<p><u>Luethy (2020) (4)</u> Preprint</p> <p>Outbreak investigation</p> <p>United States Mar 2020</p>	<p>The 2020 USA Curling Club Nationals was held Mar 7-14, 2020 in Laurel, Maryland. 88 athletes/coaches from across the US travelled to participate in the tournament, with a total attendance of 187 individuals.</p> <p>Traditional banquets were replaced with single use, disposable container packaged meals and increased cleaning was implemented during the tournament to mitigate SARS-CoV-2 transmission.</p> <p>Despite efforts, this descriptive study documents 55.6% of participants reported COVID-19 symptoms after their attendance at the tournament. Participants, volunteers and spectators were informed on Mar 18 that a person in attendance had tested positive for COVID-19. A second announcement on Mar 27 reported multiple participants had tested positive for COVID-19. A survey of players, coaches, officials, volunteers and spectators (n=187) was undertaken Sept 1-13, 2020 with an 85% (159/187) response rate and results presented in this descriptive study.</p>	<p>55.6% (104/187) of attendees reported symptoms consistent with COVID-19. A large difference was found between coaches/players and volunteers, of whom 77.3% (68/88) and 33.0% (29/88), respectively, reported symptoms.</p> <p>Testing for SARS-CoV-2 was reported by 44 individuals; 19.8% (37/187) of attendees reported positive tests for SARS-CoV-2, and 3.7% (7/187) reported negative.</p> <p>Serology testing of 73 individuals is reported, with 66 testing positive.</p> <p>Due to the large amount of mixing and length of the tournament, as well as the lack of testing available at the time of the tournament, the time and place of the transmissions cannot be determined. Similarly, no index case(s) are identified.</p>
Non-arena based sports (n=2)		
<p><u>Watson (2021) (5)</u> Preprint</p> <p>Cross-sectional study</p> <p>United States Aug-Oct 2020</p>	<p>A nationwide survey of USA high school athletes that participated in fall sports included 991 schools, 152484 athletes on 5844 teams.</p> <p>Analyses are adjusted by state COVID-19 incidence, and school instruction type.</p>	<p>2565 athletes reported COVID-19 of which 69 were directly attributed to sport contact. The total rate was 24.6 per 100 000 player-days.</p> <p>COVID-19 incidence was lower:</p> <ul style="list-style-type: none"> • Outdoor versus indoor sports (incidence rate ratio [IRR]=0.54, 95% CI=0.49-0.60, p<0.001). • Non-contact versus contact sports (IRR=0.78 [0.70-0.87], p<0.001).

		<ul style="list-style-type: none"> No difference between team versus individual sports (IRR=0.96 [0.84-1.1], p=0.49). <p>Face mask use (reported by 28% of schools) was associated with a decreased incidence in some sports:</p> <ul style="list-style-type: none"> Girls' volleyball (IRR=0.53 [0.37-0.73], p<0.001). Boys' basketball (IRR=0.53 [0.33-0.83], p=0.008). Girls' basketball (IRR=0.36 [0.19-0.63], p<0.001). Football (IRR=0.79 [0.59-1.04], p=0.10). Cheer/dance (IRR=0.75 [0.53-1.03], p=0.081). No association was found for other sports.
<p><u>Watson (2020)</u> (6) Preprint</p> <p>Cross-sectional study</p> <p>United States Aug 2020</p>	<p>A survey of soccer clubs in the USA and the incidence of COVID-19 within the club in the preceding 10 weeks.</p> <p>129 clubs responded to the survey, 124 had reinitiated soccer and included 91007 players for a median duration of 73 days. 119 clubs had progressed to group activities.</p>	<p>Among these 218 COVID-19 cases were reported among 85861 players. Youth soccer players had a lower case rate and incidence rate than the national rate for children in the US (254 v. 477 cases per 100,000; IRR = 0.511, 95% CI = [0.40-0.57], p<0.001). After adjusting for local COVID-19 incidence, there was no relationship between club COVID-19 incidence and phase of return (non-contact).</p>

GUIDANCE FOR HOCKEY DURING COVID-19

Table 2: Guidance for hockey and youth sports (n=4)

STUDY	METHOD	KEY OUTCOMES
Scientific Literature		
<p><u>DiFiori (2020)</u> (7)</p> <p>Protocol</p> <p>United States Sep 2020</p>	<p>This protocol was written by physicians associated with professional sports associations in North America (NBA, MLB, NHL, MLS, NFL) and discusses resumption of professional sports during the COVID-19 epidemic.</p>	<p>The paper does not address hockey or arena specific issues, but the following recommendations for all professional sports are of note:</p>

	<p>The focus is 'phased-in-play' so resumption of spectators is not considered within the paper.</p>	<ul style="list-style-type: none"> • Plan to switch the protocol rapidly if the level of disease transmission in the community changes; • Provide hand sanitizer and masks; • Consider heightened hygiene practices and preventative measure such as mask wearing for all involved in the sport at all times; • Ensure thorough and regular disinfection of the sport facility; • Increase ventilation and airflow in the sport facility; • Reduce the number of people in the facility significantly; • Conduct pre-event screening; and • Limit shared materials.
<p><u>Parker (2020)</u> (17) Guidance Document United States Oct 2020</p>	<p>This paper details the considerations of reopening large stadiums and arenas, specifically in the US, in the COVID-19 era.</p>	<p>No specific attention is given to arenas and the unique challenges the cold indoor air may present.</p> <p>The main focus of the paper is public health initiatives and guidance for mass gatherings and the risk points involved in the facility use.</p>
<p>National & Regional Guidance</p>		
<p><u>Hockey Canada (2020)</u> (8) Online Resource Centre Canada Jun 2020</p>	<p>As the Canadian governing body for the sport of hockey in Canada, Hockey Canada provides a central resource for return to hockey information and updates within the country. Information regarding <u>safety</u>, <u>seasonal structure</u>, <u>coaching</u>, <u>officiating</u>, <u>regulations</u> and <u>up-to-date provincial and territorial guidelines</u>.</p> <p><u>Safety guidelines</u> from Hockey Canada provide an overview of how to organize or participate in hockey during the COVID-19 pandemic. The common theme is checklists of what information to gather from local health authorities and facilities; and dissemination of that information to participants, families, etc.</p>	<p>In addition to guidance to follow local public health protocols, Hockey Canada lists common hygiene and COVID-19 prevention recommendations, such as:</p> <ul style="list-style-type: none"> • Hand washing; • Hand sanitizer use; • Containing droplets when coughing or sneezing; • Physical distancing; • Individual water bottles; and • Avoid group transportation (i.e. bus) to games. <p>Upon a positive test for COVID-19, Hockey Canada advises:</p> <ul style="list-style-type: none"> • Immediate removal of household members from hockey setting; • Further action based on advice of local public health; and

	<p>Links are provided for hockey associations within provinces and territories to provide local updates and information:</p> <ul style="list-style-type: none"> • British Columbia & Yukon <ul style="list-style-type: none"> • B.C. Hockey • Alberta <ul style="list-style-type: none"> • Hockey Alberta • Saskatchewan <ul style="list-style-type: none"> • Saskatchewan Hockey Association • Manitoba <ul style="list-style-type: none"> • Hockey Manitoba • Ontario <ul style="list-style-type: none"> • Hockey Northwestern Ontario • Ontario Hockey Federation • Hockey Eastern Ontario • Quebec <ul style="list-style-type: none"> • Hockey Quebec • New Brunswick <ul style="list-style-type: none"> • Hockey New Brunswick • Nova Scotia <ul style="list-style-type: none"> • Hockey Nova Scotia • Prince Edward Island <ul style="list-style-type: none"> • Hockey P.E.I. • Newfoundland & Labrador <ul style="list-style-type: none"> • Hockey Newfoundland & Labrador • Northwest Territories & Nunavut <ul style="list-style-type: none"> • Hockey North 	<ul style="list-style-type: none"> • Return to hockey only upon written medical authority.
<p>CDC (2020) (9)</p> <p>Guidance Document</p> <p>United States</p> <p>Dec 2020</p>	<p>CDC provides national guidance for youth sport administrators during the COVID-19 pandemic, and advises them to consult and follow their local public health officials.</p> <p>Guidance on assessing the level of risk, reducing transmission, maintaining healthy environments and operations and how to prepare strategies for when a participant becomes sick are provided.</p>	<p>Level of risk for a sport should be assessed by considering:</p> <ul style="list-style-type: none"> • Community levels of COVID-19; • Proximity of individuals during game play, practice, etc, the number of individuals exposed to one another and the duration of close proximity; • Physical intensity of activities; • Indoor vs. outdoor gathering; • Shared equipment; and • Player age and risk of severe illness. <p>With respect to hockey, the following recommendations apply:</p>

		<ul style="list-style-type: none"> • Indoor settings are higher risk than outdoor, and proper ventilation systems are needed to circulate air; • Physical distancing and mask wearing reduce risk for all participants; • High intensity activity increases risk due to increased breathing rates; • Larger teams increase potential for transmission to others; • Nonessential spectators should not be present; • Communal space (i.e. locker rooms) should have increased time between use by different groups if being utilized, and cleaning and disinfecting is required; and • Cohorting of small groups of individuals.
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EFFECTS OF TEMPERATURE AND HUMIDITY

Given the lack of published research considering SARS-CoV-2 transmission dynamics and viability within indoor ice rinks/arenas, indirect evidence was also considered. Weather related associations (temperature and humidity) summarized in a recent review with evidence up to October 1, 2020 concluded the highest incidence of COVID-19 was between the temperatures of 0-17°C, humidity had mixed results and a significant interaction was reported between temperature and humidity. Few basic research studies have described experiments on SARS-CoV-2 survival in cold temperature environments. A small experiment reported survival at 4°C for 14 days.

Table 3: Reviews of the Effect of Temperature and Humidity on SARS-CoV-2 (n=3)

STUDY	METHOD	KEY OUTCOMES
<p><u>McClymont (2020) (10)</u> Review Australia 2019-Oct 2020</p>	<p>This review considers the effect of weather, temperature and relative humidity, on the number of COVID-19 cases. The search was limited to publications up to Oct 1, 2020; and 23 articles were included in the review after full inclusion criteria were met and a quality assessment performed.</p>	<p>Ecological studies found correlations with higher transmission in areas with lower temperatures and humidity early in the epidemic. Temperature was a significant climatic factor in the 20 of the 23 studies, with a negative correlation to COVID-19 cases for 13 of the studies. Humidity was reported as significant in 12 of the 16 studies considering humidity, but with mixed results of positive (n=4) or</p>

		<p>negative (n=6) correlations or an optimal range (n=2).</p> <p>It is noted that winter conditions can contribute to increased COVID-19 transmission.</p>
<p><u>Aboubakr, 2020</u> (11)</p> <p>Review</p> <p>United States</p> <p>Jul 2020</p>	<p>This review includes studies presenting data for the stability of coronaviruses, including SARS-CoV-2.</p> <p>The persistence of coronaviruses in aerosols, on surfaces, in human fluids and in water is considered within the review, as well as the influence of temperature and humidity, pH and climatic and meteorological factors.</p>	<p>No studies on virus survival directly for arena temperatures/humidity were presented in this review.</p> <p>One study extensively tested the effects of temperature on stability of SARS-CoV-2 and found it to be highly stable at 4°C (the lowest temperature within the presented experiments) (13).</p>
<p><u>Abd El-Wahab (2020)</u> (12)</p> <p>Review</p> <p>Egypt</p> <p>Dec 2019 – Jul 2020</p>	<p>Articles concerning SARS-CoV-2 transmission from Dec 28, 2019 – July 31, 2020 were included in this review.</p> <p>302 articles are included in the review, considering three main themes of transmission: 1) SARS-CoV-2 survival; 2) transmission period and transmissibility; and 3) routes of SARS-CoV-2 spread.</p>	<p>This review captures the same experiment as (11) of SARS-CoV-2 stability at various temperatures (13).</p> <p>Empirical data that 90% of COVID-19 cases before March 22, 2020 were recorded in non-tropical countries (14) and investigations of temperature and humidity found that high temperatures were associated with lower R_e of SARS-CoV-2 (15, 16).</p>

Methods:

A daily scan of the literature (published and pre-published) is conducted by the Emerging Science Group, PHAC. The scan has compiled COVID-19 literature since the beginning of the outbreak and is updated daily. Searches to retrieve relevant COVID-19 literature are conducted in Pubmed, Scopus, BioRxiv, MedRxiv, ArXiv, SSRN, Research Square and cross-referenced with the COVID-19 information centers run by Lancet, BMJ, Elsevier, Nature and Wiley. The daily summary and full scan results are maintained in a refworks database and an excel list that can be searched. Targeted keyword searching was conducted within these databases to identify relevant citations on COVID-19 and SARS-COV-2. Search terms used included: hockey OR ((arena OR curling OR skating OR ringette OR (sports AND outbreak)) [TITLE]). Information on how air conditions can affect SARS-CoV-2 transmission were also sought from the daily scan database with a search of: temperature AND humidity AND review [TITLE]. This review contains research published up to February 12, 2021. Each potentially relevant reference was examined to confirm it had relevant data and relevant data was extracted

into the review. Grey literature was included, specifically guidance on hockey, or sports in general, from national health agencies or hockey associations within North America.

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