Emerging Evidence on COVID-19

COVID-19 Summary of SARS-CoV-2 Transmission and Singing/Wind Instruments

Introduction

What is the risk of SARS-CoV-2 virus transmission from singing or playing a wind instrument in a choir, orchestra and or practice setting with other people?

This evidence brief summarizes what is known on aerodynamic transmission of respiratory droplets and aerosols from activities that involve deep breathing and singing; the epidemiological evidence around music-related activities that resulted in transmission of SARS-CoV-2; and risk assessments, mitigation strategies or other decision analyses that may be relevant to creating music in groups. This evidence brief highlights specific literature on possible infection transmission linked to singing published until June 26, 2020.

Key Points

- The available evidence suggests the activity of singing in indoor settings can contribute to amplified infection transmission of SARS-CoV-2 if an infected person is participating. Epidemiological reports of COVID-19 clusters with high attack rates linked to choir practice in the US, Singapore, and the Netherlands, as well as a karaoke bar in South Korea provide evidence that transmission has occurred during activities that involve singing (Tables 2 and 3).
- Primary evidence on wind and brass instrument use and SARS-CoV-2 transmission could not be identified. However, one descriptive risk assessment and one grey literature study of wind instruments indicate more research should be done on the risk of SARS-CoV-2 transmission from wind instrument aerosols (Table 3). One protocol to study wind instruments and safe playing was identified (Miller, Vance, Hertzberg, & Toohey, 2020).
- No evidence on mitigation strategies for musicians was identified.
- Experimental evidence and modelled scenarios on droplet dispersion and aerosolization of SARS-CoV-2:
  - Infectious particles are commonly expelled into the surrounding air by an infected person (e.g., breathing, speaking, sneezing, singing and coughing) and these particles may transmit SARS-CoV-2 to another person when inhaled (Table 1).
  - Airborne SARS-CoV-2 particles can exist in the form of aerosols, droplets, droplet nuclei or other small particles containing viral RNA. One study reports SARS-CoV-2 virus can remain viable within aerosols for longer than three hours (van Doremalen et al., 2020).

- No simulation studies have examined particle generation during singing or wind instrument use, but studies do report on speaking and coughing. For example, 1000s of virus containing particles are estimated to be produced during a minute of loud speaking and remain airborne for longer than eight minutes (Table 1) (Stadnytskyi, Bax, Bax, & Anfinrud, 2020).
- Mathematical models informed by particle physics and aerodynamics predict respiratory and saliva particles can remain suspended in air for long enough to be inhaled by another individual, and has the potential to be dispersed some distance away from the infectious source (Vuorinen et al., 2020) (Guerrero, Brito, & Cornejo, 2020; Zhao, Qi, Luzzatto-Fegiz, Cui, & Zhu, 2020) (Feng, Marchal, Sperry, & Yi, 2020). According to mathematical models, droplet size, humidity, temperature, airflow and air turbulence all impact the movement and decay of virus containing airborne particles (Table 1).

Overview of the Evidence

The available empirical body of evidence on SARS-CoV-2 transmission during singing is linked to a few choir clusters from early in the SARS-CoV-2 outbreak. These studies are retrospective outbreak investigations that are considered to be at high risk of bias and low quality evidence.

Laboratory simulations and modelled scenarios also provide theoretical evidence to support increased transmission of SARS-CoV-2 from activities such as speaking loudly. These studies appear to have been conducted without obvious flaws in their methodology and are considered moderate to high quality evidence.

Major knowledge gaps were identified in examining the evidence underpinning the review question, additional research is needed to assess the transmission risk associated with singing or playing instruments in a group setting. There is a lack of experimental evidence that fully characterize the risk and the circumstances that lead to transmission. The risk of transmission events from singing and playing wind instruments in a choir, orchestra and/or practice setting with other people is unknown, but theoretical evidence and recorded clusters attributed to this activity indicate that there is a risk.

CONTENTS

SARS-COV-2 DROPLETS AND AEROSOLS

Six experiments and five models investigate aerosolization of SARS-CoV-2 and characterize some of the circumstances under which aerosolization or droplet dispersions occur. Infectious particles are commonly expelled into the surrounding air by an infected person (e.g., breathing, speaking, sneezing, singing or coughing) and these particles may transmit SARS-CoV-2 to another person when inhaled (Table 1). Risk of transmission likely depends on the characteristics of the environment, the activity, the distance from and duration of time spent with an infected person. Airborne SARS-CoV-2 particles can exist in the form of aerosols, droplets, droplet nuclei or other small particles containing viral RNA. van Doremalen provides primary evidence to support the viability of SARS-CoV-2 virus particles in aerosols. The study reports SARS-CoV-2 virus can remain viable within aerosols for longer than three hours (van Doremalen et al., 2020).

No simulation studies have examined particle generation during singing or wind instrument use, but studies reported on speaking and coughing. Simulations have successfully visualized thousands of minute respiratory droplets and aerosols that are generated during normal speech, and remain suspended in air for longer than eight minutes (Anfinrud, Bax, Stadnytskyi, & Bax, 2020; Chanpong, Tang, Rosenczweig, Lok, & Tang, 2020; Stadnytskyi et al., 2020). Additionally, 1,000s of virus containing particles are estimated to be produced during a minute of loud speaking, and remain airborne for longer than eight minutes (Stadnytskyi et al., 2020). Coughing also generated respiratory droplets and aerosol that traveled average distances of two and a half meters and a maximum of four meters, as well as substantial droplet splatter on nearby healthcare workers (Chanpong et al., 2020; Loh et al., 2020). As such it is likely singing can also lead to the dispersion of infectious particles.

Mathematical models informed by particle physics and aerodynamics predict respiratory and saliva particles can remain suspended in air for long enough to be inhaled by another individual. And have the potential to be dispersed some distance away from the infectious source (Vuorinen et al., 2020) (Guerrero et al., 2020; Zhao et al., 2020) (Feng et al., 2020). According to mathematical models, droplet size, humidity, temperature, air flow, and air turbulence all impact the movement and decay of virus containing airborne particles (Table 1).

Table 1: Primary literature on SARS-CoV-2 aerosol and droplets

Publication Title	Key Outcomes	Reference
Experimental and Simulation Studies		
Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1	The stability and decay of SARS-CoV-2 and SARS-CoV-1 in aerosols was estimated using a Bayesian regression model SARS-CoV-2 virus remained viable in aerosols up to three hours hrs (duration of the experiment), with a reduction in infectious titer from $10^{3.5}$ to $10^{2.7}$ $TCID_{50}$ per liter of air.	(van Doremalen et al., 2020)
The impact of high-flow nasal cannula (HFNC) on coughing	A simulation study using healthy volunteers (n=5) found cough-generated droplets spread a mean distance of 2.48 meters (1.03 standard deviation) at baseline, maximum of 3.90 meters.	(Loh et al., 2020)

distance: implications on its use during the novel coronavirus disease outbreak	When wearing well-fitting High Flow Nasal Cannula, mean cough generated droplet spread was 2.91 meters (1.09) with a maximum distance of 4.50 meters.	
Aerosol-generating procedures and simulated cough in dental anesthesia	Aerosol and droplet splatter was visualized using a Glo Germ system. Simulated cough was found to produce more extensive splatter than test aerosol generating dental procedures.	(Chanpong et al., 2020)
Could SARS-CoV-2 be transmitted via speech droplets?	A planar beam of laser light passing through a dust-free enclosure is used to detect saliva droplets emitted while speaking. The investigation provides visual evidence that infection transmission from droplets and aerosols is possible. Preliminary observations find thousands of respiratory and saliva droplets emitted while speaking are much smaller than those emitted during coughing, and simple phrases such as "stay healthy" can generate thousands of small droplets with the potential to transmit infection. Researchers state additional studies are necessary to assess the viral titre present in speech-induced droplets based on COVID-19 severity.	(Anfinrud et al., 2020)
The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission	Sensitive planar beam laser light scattering observations and aerodynamic particle sizer (APS) measurements are used to visualize droplet dispersion and decay. The experiments find droplets generated during normal speech to decay within 8-14 minutes in close stagnant environments (similar to indoor environments, particularly with poor ventilation), and the longest decay times were observed for droplets with a diameter ≥12 µm when exiting the mouth. The researchers estimate 1 minute of loud speaking can generate a minimum of 1,000 virion containing droplet nuclei that remain airborne for more than 8 minutes. The findings suggest air suspended virus containing particles could be inhaled by others.	(Stadnytskyi et al., 2020)
Mathematical Models		
Publication Title	**Key Outcomes**	**Reference**
COVID-19: Effects of weather conditions on the propagation	A comprehensive mathematical model was established to explore speech generated droplet evaporation, heat transfer and kinematics under different conditions (e.g., temperature, humidity and ventilation). Low temperature and high humidity	(Zhao et al., 2020)

of respiratory droplets	facilitate droplet transmission and dispersion, but supresses the formation of aerosols. On the other hand, high temperature and low humidity promotes rapid loss of respiratory droplet mass (from evaporation) and reduce droplet travel distance, but these conditions increase transmission risk from aerosol particles. The study concludes current social distancing recommendations may not be sufficient to diminish airborne transmission risks as droplets can travel distances up to 6 meters.	
COVID-19. Transport of respiratory droplets in a microclimatologic urban scenario	Examined the spread of respiratory droplets in outdoor environments by applying a computational model of a sneezing person in an urban scenario under a medium intensity climatological wind. The spread of respiratory droplets is characterized by the dynamics of droplet size: larger droplets (400 – 900 µm) are spread between two to five meters during 2.3 seconds while smaller droplets (100 – 200 µm) are transported between eight and eleven meters in 14.1 seconds when influenced by turbulent wind.	(Guerrero et al., 2020)
Influence of wind and relative humidity on the social distancing effectiveness to prevent COVID-19 airborne transmission: A numerical study	Air transmission of cough droplets with condensation and evaporation effects are modeled between 2 virtual humans under different environments and wind velocities. Micro-droplets follow airflow streamlines and can be deposited on virtual human bodies (including head regions) at greater than 3.05 meter (10 feet) distances. High Relative humidity (99.5%) also leads to larger droplet sizes and greater deposition of cough droplets on surfaces (due to hygroscopic growth effects). Suspended micro droplets could be transmitted between the 2 virtual humans in less than 5 seconds. The study concludes due to environmental wind, convection effects, and relative humidity on respiratory particles emitted by humans, the frequently recommended 1.83 meters (six feet) of social distancing may not be sufficient to prevent inter-person aerosol transmission.	(Feng et al., 2020)
Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission	Available evidence on aerosol transport in air is combined with 0D-3D simulations in physics-based models and theoretical calculations. Monte Carlo simulations indicate droplets produced by speech and cough (diameter < 20 µm) can become airborne and linger in the air from 20 minutes up to 1 hour, and be inhaled by others. The exposure time to inhale 100 aerosols (assumed to be an adequate infectious dose) is variable based on	(Vuorinen et al., 2020)

by inhalation indoors	the situation and can range from one second, to 1 minute, to 1 hour. 3D computational fluid dynamic (CFD) simulations suggest aerosols (dp <20 µm) can be transported over 10 meter distances in generic environments, dependent on relative humidity and airflow. Finally the rapid drying of expelled mucus droplets would yield droplet nuclei and aerosols which could potentially carry airborne virus particles. Such droplets (initial particle diameter of 50 µm to 100 µm) could remain airborne for approximately 20 seconds to 3 minutes.	

COVID-19 CLUSTERS ATTRIBUTED TO SINGING

Five published articles were identified that document outbreaks of COVID-19 related to singing and/or playing instruments. One outbreak of Skagit Valley, WA choir COVID-19 cluster with a secondary attack rate of 53-87% (Hamner et al., 2020) and a mathematical model based estimation of emissions generated in this scenario (Miller et al., 2020) suggest infection transmission in this cluster primarily occurred from sharing an indoor space with a single infectious individual who was singing. Multiple case cluster summaries highlight singing class, karaoke, music concerts and choir practice clusters from Japan, and Singapore (Furuse et al., 2020; Dalton, Katelaris, & Wilson, 2020., Wei et al., 2020). Risk of transmission depends on the characteristics of the environment, the activity, the distance from and duration of time spent with an infected person (Waddell., 2020).

Table 2: Literature on epidemiological investigations that (partially) attribute singing to transmission

Publication Title	Key Outcomes	Reference
High SARS-CoV-2 attack rate following exposure at a choir practice — Skagit County, Washington, March 2020	A choir practice in Washington, US involving 61 singers, including the symptomatic index case, led to 32 confirmed and 20 probable secondary COVID-19 cases (attack rate = 53.3% to 86.7%); 3 patients were hospitalized, and 2 died. Authors conclude transmission was likely facilitated by close proximity (within 6 feet) during singing practice and augmented by the act of singing.	(Hamner et al., 2020)
Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale	Case study of the Skagit County choir outbreak that explores infection risk variability based on the rates of removal of respiratory aerosols by ventilation, deposition onto surfaces and viral decay. Due to the high secondary attack rate a common fomite and person to person transmission are assumed unlikely. Shared	(Shelly L. Miller et al., 2020)

superspreading event	indoor air at the practice site, and high emissions of respiratory aerosols during singing are assumed to be the dominant factors linked to infection transmission. Modeled airborne infection risk assessment infers an emission rate of E = 970 (± 390) quanta per hour in this scenario from the single infectious index case.	
Presymptomatic Transmission of SARS-CoV-2 — Singapore, January 23–March 16, 2020	Investigation of 7 COVID-19 clusters identified in Singapore find asymptomatic transmission to have occurred. In two independent clusters infection transmission is attributed to multiple women attending music class (Cluster B, Cluster F) with confirmed cases.	(Wei et al., 2020)
Clusters of Coronavirus disease in communities, Japan, January-April 2020	Investigation of 61 clusters of >5 cases in Japan Jan 15- Apr 4. 18 (30%) healthcare facilities; 10 (16%) care facilities of other types, such as nursing homes and day care centers; 10 (16%) restaurants or bars; 8 (13%) workplaces; 7 (11%) music-related events, such as live music concerts, chorus group rehearsals, and karaoke parties; 5 (8%) gymnasiums; 2 (3%) ceremonial functions; and 1 (2%) transportation-related incident in an airplane. The largest non–healthcare-related cluster was >30 persons who attended a live music concert, including performers, audience members, and event staff. Many COVID-19 clusters were associated with heavy breathing in close proximity, such as singing at karaoke parties, cheering at clubs, having conversations in bars, and exercising in gymnasiums.	(Furuse et al., 2020)
Open with care: minimising COVID-19 superspreading settings in Australia	Risk benefit evaluation Karaoke rooms and choir practice where singing is involved is viewed as possible amplification of transmission risk due to people congregated in closely and the action of singing. Churches and religious gathering outbreaks have been recorded in the USA, S. Korea and Singapore. Characteristics of religious gatherings may increase risk of transmission due to activities such as singing, hugging and handshakes during greetings and services, passing of sacramental objects, close seating arrangements and sharing of food and refreshments. The article warns, in the Australian context, lifting of restrictions should be done carefully. In conditions of very low community spread and high proportions of susceptible populations, these superspreading events may be very important sources of cases.	(Dalton, Katelaris, & Wilson, 2020)

GREY LITERATURE ON COVID-19 RISK AND SINGING AND WIND INSTRUMENTS

This table summarizes relevant grey literature. Two outbreaks, one in the Netherlands involving a large choir and orchestra and a second associated with a karaoke outbreak in South Korea. A risk assessment, an experiment and a protocol for future research on the risk of transmission due to playing wind instruments. As well as two previously conducted evidence summaries by Alberta (May 22) and Newfoundland (Jun 1), which also capture several guidance documents and position statements.

Table 3: Grey literature on infection transmission attributed to singing and wind instruments

Publication Title	Key Outcomes	Reference
Wind instrument aerosol in Covid Era - COVID-19 and horns, trumpets, trombones, euphoniums, tubas, recorders, flutes, oboes, clarinets, saxophones and bassoons	Risk Assessment This risk assessment provides an overview of the different activities involved in playing wind instruments that may result in aerosols or direct transmission. • There is no direct evidence, but indirect evidence suggests it may exceed normal background risk of transmission. • The authors describe common practices among musicians that have the potential to spread the virus. The practice of sharing or touching other musicians' reeds was described as high risk and there were no recommendations for disinfection of reeds. • The authors conclude there is insufficient evidence to properly assess the risk of SARS-CoV-2 transmission due to playing instruments with other people.	(Schwalje & Hoffman, 2020)
Aerosol generation from playing band instruments and risk of infectious disease transmission	This is a protocol for a study being conducted at University of Colorado. The goal of this project is to provide measurements and risk modelling estimates in a timely manner to better understand particle emissions from playing band instruments. Proposed four activities: 1. Flow imaging studies to qualitatively document the emission and particulate plume through photography and lasers 2. Chamber studies to measure particle generation rates from the following activities:	(Shelly L. Miller et al., 2020)

	a. 5 woodwinds – flute, clarinet, oboe, saxophone, bassoon b. 4 brass – french horn, trumpet, trombone, tuba c. The 4 vocal ranges – soprano, alto, tenor, bass d. Musical theatre – talking, monologue, singing, dancing (male and female actors) e. Elementary – male and female in grades 3-5 f. Aerobic simulation (marching band, show choir, dance, etc.) 3. Field rehearsal studies measuring concentrations in a rehearsal room with multiple players the University of Colorado Boulder (contingent upon IRB and campus approval) 4. Modelling of risk of transmission using the Wells-Riley Model	
Bamberg Symphony Orchestra: Scientists measure aerosol emissions	On-line publication (in German) Scientists at the Bamberg Symphony Orchestra use air currents to measure how many aerosols are emitted by a trombone, clarinet or horn. The emitted suspended matter is considered to represent the potential for air contaminated with SARS-CoV-2 to be expelled from the instrument if the musician was infected.	("Bamberg Symphony Orchestra: Scientists measure aerosol emissions," 2020)
(LEAD) Itaewon-tied cases rise to 153, karaoke facilities emerge as infection routes	Online newspaper article Infections in Seoul, South Korea linked to nightspots in the neighborhood of Itaewon, karaoke facilities are suspected infection transmission sites.	("(LEAD) Itaewon-tied cases rise to 153, karaoke facilities emerge as infection routes," 2020)
That one passion that did go on, with disastrous consequences.	Online newspaper article This outbreak involved 102 COVID-19 cases among 130 members of a choir and orchestra in Amsterdam, Netherlands. At the beginning of the outbreak, the group continued to practice despite members of the choir becoming ill. Based on the sequence of events and illnesses, there were potentially multiple transmission events.	(van der Lint, P., 2020)
COVID-19 quick response report: Choirs and COVID-19	Quick response report on the evidence with respect to choirs and COVID-19 up to June 3, 2020. The authors summarize many of the guidance documents, expert opinions and evidence on choirs and transmission of SARS-CoV-2.	(Williams, S and Navarro, P., 2020)

Singing as a risk for transmission of SARS-CoV-2 virus	Rapid review on the evidence and guidance around singing as a risk of transmission. It was last evaluated May 22, 2020. The review includes non-SARS-CoV-2 literature relevant to singing and the potential to spread pathogens. The report on choir related transmission events of influenza A, and tuberculosis.	(Kania-Richmond, A and Sharpe H., 2020)

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 literature on the WHO COVID literature list, and COVID-19 information centers run by Lancet, BMJ, Elsevier 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 is conducted within these databases to identify relevant citations on COVID-19 and SARS-CoV-2. Search terms used included: sing, karaoke, choir, wind and instrument, music, singing, vocalize, religious, church. An additional search for grey literature was conducted using search strings (COVID-19 or SARS-CoV-2) AND (choir or music or (wind and instrument)) in google. Previously conducted reviews were sought from the NCCMT repository, CADTH, and SPOR evidence alliance.

Each potentially relevant reference was examined to confirm it had relevant data and relevant data is extracted into the review. This review contains research published up to June 26, 2020.

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