National Collaborating Centre for Methods and Tools

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School of Nursing | McMaster University

Rapid Review: What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument, and how can these risks be mitigated?

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Date: February 3, 2021

Suggested Citation:

National Collaborating Centre for Methods and Tools. (2021, February 3). *What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument, and how can these risks be mitigated?* https://www.nccmt.ca/knowledge-repositories/covid-19-rapid-evidence-service.

Please Note: An update of this review may be available. Access the most current version of this review by visiting the National Collaborating Centre for Methods and Tools COVID-19 Rapid Evidence Service at the above link.

The National Collaborating Centre for Methods and Tools (NCCMT) is hosted by McMaster University and funded by the Public Health Agency of Canada. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada.

The authors declare they have no conflicts of interest to report.

Executive Summary

Background

Singing and playing wind instruments produce respiratory droplets and aerosols and may also generate fomites (i.e., contaminated surfaces). Public health guidance on the extent to which any of these activities contributes to COVID-19 transmission may assist community and arts organizations to respond effectively to risks associated with the pandemic.

This rapid review was produced to support public health decision makers' response to the coronavirus disease 2019 (COVID-19) pandemic. This review seeks to identify, appraise, and summarize emerging research evidence to support evidence-informed decision making.

This rapid review includes evidence available up to January 4, 2021 to answer the question: **What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument, and how can these risks be mitigated?**

Key Points

- The available evidence points to a potential risk of COVID-19 transmission associated with singing. There have been case reports of outbreaks and "super-spreader events" associated with group singing (choir practice, places of worship), although the included case reports describe events early in the pandemic when infection control measures were not routinely implemented. It is unclear whether the risk of transmission of COVID-19 via singing is from aerosolizing of respiratory particles, expulsion of large droplets, and/or close group social behaviours. Modelling studies show the aerosol quantity and velocity of droplets when singing is higher than when breathing or speaking. The overall certainty of this evidence is very low, and findings are very likely to change as more evidence becomes available.
- There is no clear evidence of transmission associated with playing wind instruments, although modelling studies demonstrate that the virus could theoretically be transmitted by this means. Modelling studies show variation in the amount of aerosols generated by different instruments. The aerosol quantity and velocity of droplets associated with woodwind or brass instruments is not found to be significantly more than breathing, speaking or coughing in most studies. The overall certainty of this evidence is very low, and findings are very likely to change as more evidence becomes available.
- Available reviews of low quality suggest that the risk of transmission through singing and instrument playing could be mitigated through standard public health measures such as screening, distancing, surface sanitizing, respiratory etiquette, hand hygiene, and mask use when possible, along with interventions specific to these settings, such as increased ventilation, shorter schedules, and outdoor venues. The effectiveness of these strategies at reducing transmission has not been demonstrated. Modelling and simulation studies show the potential effectiveness of high volume ventilation, air purifiers placed above the musician, and instrument/bell covers (although not always practical for playing). The effectiveness of these strategies in reducing actual transmission has not been demonstrated. The overall certainty of this evidence is very low, and findings are very likely to change as more evidence becomes available.

Overview of Evidence and Knowledge Gaps

- The evidence has not clearly separated the transmission risk associated with singing from other risks present during singing outbreak events, such as crowding, close contacts, gathering in large groups, enclosed spaces, poor ventilation, long duration of contact, social interactions, backstage gatherings, or sharing food, drinks, equipment and transportation. More research is needed to determine any additional risk associated with singing.
- Although modelling studies have demonstrated the potential for singing and woodwind/brass instrument playing to produce aerosolized particles, droplets and fomites, the actual transmission of COVID-19 infection has not been consistently demonstrated.
- More research is needed to determine whether the risk of transmission of COVID-19 via singing is from aerosolizing of respiratory particles, expulsion of large droplets, and/or close group social behaviours.
- More research is needed on the effectiveness of general infection control measures (e.g., handwashing, distancing, masking as appropriate) and specific mitigation strategies in reducing transmission of infection associated with singing or wind instrument playing.
- There is a degree of overlap in the studies included in the review articles, leading to a risk of over-estimating the associations described when drawing from all the available reviews. However, the trends described in each review are consistent, and those have been described in this review.

Methods

Research Question(s)

What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument, and how can these risks be mitigated? (Transmission to audience members was excluded from this review.)

Search

On January 4, 2021, the following databases were searched using key terms: singing, sing, singer, vocal, vocalize, vocalise, vocalization, vocalist, "wind instrument", "wind player", "wind musician", "brass instrument", "brass player", "brass musician", musician, musical, “woodwind", trumpet, trombone, euphonium, tuba, flugelhorn, clarinet, saxophone, bassoon, piccolo, vuvuzela, philharmonic, orchestra, symphony, "school band", choir, choral, rehearsal, rehearse, "music group", accompanist, opera, operetta, "bell cover", "instrument cover", "musical theatre", flute, oboe, "french horn".

- Pubmed’s curated COVID-19 literature hub: LitCovid
- World Health Organization’s Global literature on coronavirus disease
- COVID-19 Evidence Alerts from McMaster PLUS™
- COVID-19 Living Overview of the Evidence (L·OVE)
- McMaster Health Forum
- Prospero Registry of Systematic Reviews
- MedRxiv preprint server
- NCCMT COVID-19 Rapid Evidence Reviews
- NCCEH Environmental Health Resources for the COVID-19 Pandemic
- NCCID Disease Debrief
- Uncover (USHER Network for COVID-19 Evidence Reviews)
- Centers for Disease Control and Prevention’s Morbidity and Mortality Weekly Report (MMWR)
- Alberta Health Services
- Public Health Ontario
- Public Health England
- Institut national de santé publique du Québec (INSPQ)
- ERIC via ProQuest

A copy of the full search strategy is available at this [link].

A call for relevant articles was also issued via email to Canadian national and provincial music organizations. Several articles were suggested, and two met the inclusion criteria for this review.

Study Selection Criteria

The search results were first screened for recent guidelines and syntheses. Single studies were included if no syntheses were available, or if single studies were published after the search was conducted in the included syntheses. English-language, peer-reviewed sources and sources published ahead-of-print before peer review were included. Surveillance sources were excluded. When available, findings from syntheses and clinical practice guidelines are presented first, as these take into account the available body of evidence and, therefore, can be applied broadly to populations and settings.

Question 1: What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument?

	Inclusion Criteria	Exclusion Criteria
Population	Musicians/performers (wind players, brass players, singers)	Instruments that can be played while masked (string instruments, percussion, piano, etc.) Studies exclusive to instruments that can be played while masked, e.g., string quartet
Intervention	Singing/playing an instrument Exposure to people singing/playing an instrument (e.g., choir/orchestra conductor)	Audiences Performing arts that include no singing/wind instrument components, e.g., dance, theatre
Outcomes	COVID-19 infection and/or secondary infection and/or outbreaks Detection of virus in simulated environment	
Setting	Bands, choirs, music groups in all settings, including professional, religious, and school Indoor and outdoor settings	Bars, pubs

Question 2: What strategies are effective at minimizing risk of transmission during musical activities?

	Inclusion Criteria	Exclusion Criteria
Population	Musicians/performers (wind players, brass players, singers) Musician to audience transmission	Instruments that can be played while masked (string instruments, percussion, piano, etc.) Studies exclusive to instruments that can be played while masked, e.g., string quartet Audience to audience transmission
Intervention	Strategies for prevention & control Exposure to people singing/playing an instrument (e.g., choir/orchestra conductor)	Performing arts that include no singing/wind instrument components, e.g., dance, theatre
Outcomes	COVID-19 infection and/or secondary infection and/or outbreaks Detection of virus in simulated environment	
Setting	Bands, choirs, music groups in all settings, including professional, religious, and school Indoor and outdoor settings	Bars, pubs

Data Extraction and Synthesis

Data relevant to the research question, such as study design, setting, location, population characteristics, interventions or exposure and outcomes were extracted when reported. We synthesized the results narratively due to the variation in methodology and outcomes for the included studies.

Appraisal of Evidence Quality

We evaluated the quality of included evidence using critical appraisal tools as indicated by the study design below. Quality assessment was completed by one reviewer and verified by a second reviewer. Conflicts were resolved through discussion. For modelling studies, a suitable quality appraisal tool was not found, and the review team did not have the expertise to assess methodological quality. Studies for which quality appraisal has not been conducted are noted within the data tables.

Study Design	**Critical Appraisal Tool**
Synthesis	Assessing the Methodological Quality of Systematic Reviews (AMSTAR) AMSTAR 1 Tool
Case Report	Joanna Briggs Institute (JBI) Checklist for Case Reports

Completed quality assessments for each included study are available on request.

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach was used to assess the certainty in the findings based on eight key domains.

In the GRADE approach to quality of evidence, **observational studies,** as included in this review, provide **low quality** evidence, and this assessment can be further reduced based on other domains:

- High risk of bias
- Inconsistency in effects
- Indirectness of interventions/outcomes
- Imprecision in effect estimate
- Publication bias

and can be upgraded based on:

- Large effect
- Dose-response relationship
- Accounting for confounding

The overall certainty in the evidence for each outcome was determined taking into account the characteristics of the available evidence (observational studies, some not peer-reviewed, unaccounted-for potential confounding factors, different tests and testing protocols, lack of valid comparison groups). A judgement of 'overall certainty is very low' means that the findings are very likely to change as more evidence accumulates.

Findings

Summary of Evidence Quality

This document includes five completed syntheses, 22 single studies, and three in progress single studies for a total of 30 publications included in this review. The quality of the evidence included in this review is as follows:

Research Question	Evidence included		Overall certainty in evidence based on completed evidence
Question 1: What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument?	Completed syntheses Single studies In progress single studies	5 18 2	Low 2 High; 1 Moderate; Others not appraised Not appraised
Question 2: What strategies are effective at minimizing risk of transmission during musical activities?	Completed syntheses Single studies In progress single studies	5 8 2	Low Not appraised Not appraised

Warning

Given the need to make emerging COVID-19 evidence quickly available, many emerging studies have not been peer reviewed. As such, we advise caution when using and interpreting the evidence included in this rapid review. We have provided a summary of overall certainty of the evidence to support the process of decision making. Where possible, make decisions using the highest quality evidence available.

A number of mathematical modelling studies are emerging related to COVID-19. While these studies may provide important estimates, their ultimate usefulness depends on the quality of the data that is entered into the model. Given the constantly evolving nature and changing understanding of COVID-19 around the world, a high degree of caution is warranted when interpreting these studies.

Important to this question, we did not assess the methodological quality of modelling or simulation studies. Due to the highly technical nature of these studies, we highly recommend consulting a content-area expert to inform decision making.

Question 1: What is known about the risk of transmission of COVID-19 during musical activities such as singing or playing a wind instrument?

Table 1: Syntheses

Reference	Date Released	Description of Included Studies	Summary of Findings	Quality Rating: Synthesis	Quality Rating: Included Studies
Public Health Ontario. (2020, Nov 18). COVID-19 Transmission from Singing and Playing Wind Instruments: What We Know So Far.	Nov 18, 2020 (Search completed Oct 26, 2020)	This updated rapid review added 22 new studies to an unspecified total: • 10 experimental • 4 observational • 2 review • 6 grey literature reports	Limited evidence suggests transmission has occurred during singing (e.g., high secondary attack rates among choir members). No studies confirm transmission from playing instruments.	Low	Not reported ***NOT PEER REVIEWED***

National Collaborating Centre for Environmental Health. (2020, Sep 23). COVID-19 Risks and precautions for the performing arts.	Sep 23, 2020 (Search date not provided)	This rapid review included 21 media and literature reports of COVID-19 clusters and outbreaks associated with singing, dance, theatre, and bands.	The majority of COVID-19 clusters and outbreaks associated with music-related events are linked to large, indoor group gatherings, with close interactions over long durations. Evidence suggests that the transmission pathway is via respiratory droplets and short-range aerosols, the concentration, quantity, and size of which are increased during vocalization – especially when loud and exaggerated – compared to less intense respiratory activities. Vocalization produces fewer aerosols per event than coughing or sneezing but the total produced over time, particularly by a group, could be greater. Playing wind instruments may release more particles, at a higher velocity, than shouting, but the number is significantly lower than coughing. Drainage of breath condensate from brass instruments may pose a risk of droplet, aerosol, or fomite transmission. More research is needed to confirm and quantify these risks.	Low	Not reported ***NOT PEER REVIEWED***
Public Health Agency of Canada (2020, Jul 5). Emerging Evidence on COVID-19: COVID-19 Summary of SARS-CoV-2 Transmission and Singing/Wind Instruments.	Jul 5, 2020 (Search completed Jun 26, 2020)	This evidence brief included: • 5 experimental and simulation studies • 4 mathematical models • 5 published epidemiological investigations • 7 reports from the grey literature	Singing in indoor settings may increase the risk of COVID-19 transmission if an infected person is participating. The transmission route may be via aerosols, droplets, droplet nuclei or other small particles containing viral RNA. More research is needed to determine risk of transmission from instrument use.	Low	Range from high risk of bias and low quality (empirical evidence) to moderate/ high quality (simulation and modelling studies) ***NOT PEER REVIEWED***

National Collaborating Centre for Environmental Health. (2020, Jul 1). COVID-19 Risks and Precautions for Choirs.	Jul 1, 2020 (Search date not provided)	This rapid review included media reports and limited published evidence (study design not described).	The risks associated with singing in groups are the same as those associated with large gatherings; it is unclear to what degree loud vocalization also contributes to transmission in these settings. In one outbreak described, given the precautions followed (social distancing, hand hygiene), inhalation of respiratory aerosols in shared air over a prolonged duration is thought to have been the route of transmission. Potential routes described in other outbreaks include large respiratory droplets or surface transmission (e.g., fomites). Risk factors associated with the reported singing outbreaks included: • Crowding, close contacts • Gathering in large groups • Enclosed spaces, poor ventilation • Long duration of contact • Social interactions, greetings, backstage gatherings • Sharing food, drinks, equipment, transportation	Low	Not reported ***NOT PEER REVIEWED***
Alberta Health Services. (2020, May 22). Topic: Singing as a risk for transmission of SARS-CoV-2 virus.	May 22, 2020 (Search date not provided)	This rapid review included: • 2 epidemiological reports • 5 epidemiological studies* • 1 primary study* *3 epidemiological studies and 1 primary study analyzed other infectious diseases, not COVID-19, specifically	There is a potential risk associated with singing and COVID-19 transmission, although the evidence is limited. There have been some reports of outbreaks and "super-spreading" events associated with group singing (choir practice, places of worship). It is unclear whether the risk of transmission of COVID-19 via singing is from aerosolizing of respiratory particles, expulsion of large droplets, and/or close group social behaviours.	Low	Low (for one study; quality of other included studies not reported) ***NOT PEER REVIEWED***

Table 2: Single Studies

Reference	Date Released	Study Design	Instruments	Setting	Summary of findings	Quality Rating:
Case reports						
Charlotte, N. (2020). High rate of SARS-CoV-2 transmission due to choir practice in France at the beginning of the COVID-19 pandemic. *Journal of Voice*. Epub ahead of print.	Dec 23, 2020	Case study	Voice	Choir rehearsal n=25 adult male singers, 1 conductor, 1 accompanist	This study describes a cluster of COVID-19 infections linked to a choir rehearsal held on Mar 12, 2020 in France. There were 19 cases of COVID-19 identified among those who attended the rehearsal, with a secondary attack rate of 70%. No choristers had detectable symptoms of COVID-19 between Mar 2 and 12, Chairs were separated less than 6ft for the duration of the rehearsal, and face-to-face discussion or socialization were minimized. Choristers were not masked. The room was not ventilated. Some attendees had previously attended a separate choir's rehearsals on Mar 9 and 11. No distancing was observed at these rehearsals.	High

Miller, S. L., Nazaroff, W. W., Jimenez, J. L., Boerstra, A., Buonanno, G., Dancer, S. J., … Noakes, C. (2020). Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley chorale superspreading event. *Indoor Air*. Epub ahead of print. Hamner, L., Dubbel, P., Capron, I., Ross, A., Jordan, A., Lee, J., … Leibrand, H. (2020). High SARS-CoV-2 attack rate following exposure at a choir practice - Skagit County, Washington, March 2020. *MMWR Morbidity and Mortality Weekly Report*, *69*(19), 606-610.	Sep 26, 2020 May 15, 2020	Case study	Voice	Choir rehearsal n=61 (amateur chorists; adult men and women)	This study describes a COVID-19 outbreak following a choir rehearsal held on Mar 10, 2020, in Washington, USA. (This event was described by Miller et al. and Hamner et al.) 53 attendees became ill with COVID-19 symptoms, of which 33 were confirmed cases of COVID-19 and 20 were probable cases. Three of the symptomatic people were hospitalized, and two died. The attack rate was 53.3-86.7%. One person in attendance had cold-like symptoms that began three days prior to the rehearsal. Precautions used during the rehearsal included using hand sanitizer and refraining from hugging and handshakes. Chairs were separated less than 6ft for the duration of the rehearsal. Physical distancing was not maintained. Snacks were served. The rehearsal lasted 2.5 hours. Ventilation during that time is unknown. A previous choir rehearsal was held on Mar 3; however, the odds of becoming ill after the Mar 3 rehearsal were 17.0 greater (95% CI = 5.5-52.8) for those who attended the rehearsal than those who did not, compared to the Mar 10 rehearsal, where the odds were 125.7 times greater (95% CI = 31.7-498.9) for those who attended the rehearsal.	Moderate High

Aerosol emission studies						
Abraham, A., He, R., Shao, S., Kumar, S. S., Wang, C., Guo, B., … Hong, J. (2020). Risk assessment and mitigation of airborne disease transmission in orchestral wind instrument performance. *Preprint.*	Dec 24, 2020	Aerosol emission test	Wind instruments: trumpet, trombone, bass trombone, French horn, tuba, flute, bassoon, oboe, clarinet, and bass clarinet	Concert hall	Aerosol emissions from musicians playing brass and woodwind instruments playing at three distinct volumes were measured. Correlations between aerosol emission in relation to pitch and note duration were calculated. For brass instruments, there is an inverse correlation between note duration and aerosol concentration, i.e., more aerosols are generated when notes are shorter and/or change quicker. This relationship is strongest for trumpet and weakens for larger instruments. For woodwinds, there is a possible correlation between playing notes in the upper range of the instrument and aerosol emissions for clarinet, oboe, and bass clarinet. Flute and bassoon were not tested. Overall, it was found that the radius of airflow from all instruments tested did not exceed 6ft, but the concentration of aerosols within this radius varied by instrument and music type. Limitations of this study include: • Musical phrasing and articulation not taken into account • Study is limited to 11 instruments, and emissions from other wind instruments may differ	Not appraised ***PREPRINT***

Spahn, C., Hipp, A., Schubert, B., Axt, M. R., Stratmann, M., Schmölder, C., & Richter, B. (2020). Airflow and air velocity measurements while playing wind instruments, with respect to risk assessment of a SARS-CoV-2 infection. *Preprint*.	Dec 23, 2020	Aerosol emission	Wind instruments: Trumpet, trombone, horn, tuba, alto flute, piccolo, oboe, English horn, clarinet, bass clarinet, bassoon, contrabassoon, tenor saxophone, and recorder	Concert hall	Airflow patterns released from instrument from 1m, 1.5m, and 2m were measured during different pitches and dynamics and articulations and flow was visualized. Airflow for most instruments was <0.1m/s at all distances, with measurements greater than this only recorded for tuba (0.13m/s at 1m), oboe (0.15m/s at 1m and 0.12m/s at 1.5m), and contrabassoon (0.1m/s at 1m). Pitch and volume were not observed to affect air movements. Limitations of this study: • This study measured airflow, but the potential dispersion of SARS-CoV-2 droplets remains unknown • Study was conducted with professional classical musicians, and these results may not be transferable to amateurs or other musical genres • Analysis was only measured once for each instrument; reproducibility was not explored • No analysis was done on group playing	Not appraised ***PREPRINT***
Colorado State University. (2020, Dec 2). Reducing Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safe Return from COVID19.	Dec 2, 2020	Aerosol emission	Wind instruments, voice	Laboratory	Preliminary results of dispersion of aerosols in singers while singing with and without masks and while playing instruments with and without a cover are presented. Some instruments produce more aerosols than others (trumpet and tuba produce the highest), but there is variation by performer. Masks and bell covers reduce droplet dispersion. More details will be forthcoming in this ongoing study.	Not appraised ***NOT PEER REVIEWED***

Echternach, M., Gantner, S., Peters, G., Westphalen, C., Benthaus, T., Jakubass, B., ... Kniesburges, S. (2020). Impulse dispersion of aerosols during singing and speaking: A potential COVID-19 transmission pathway. *American Journal of Respiratory and Critical Care Medicine, 202*(11), 1584-1587.	Dec 1, 2020	Aerosol emission	Professional singers	Broadcast studio	Dispersion of aerosols in professional singers while singing and speaking at two distinct levels of loudness were compared. While singing, median dispersion of aerosols was 0.86m for "loud" volumes and 0.78m for "soft" volumes. While speaking, median dispersion of aerosols was 0.82 for "loud" volumes and 0.74 for "soft" volumes. The differences were not statistically significant. Very little aerosol dispersion to either side of the study subject was noted. Limitations of this study include that only professional singers were analyzed. Furthermore, this study only explored aerosol dispersion and not risk of COVID-19 transmission.	Not appraised
Lelieveld, J., Helleis, F., Borrmann, S., Cheng, Y., Drewnick, F., Haug, G., ... Pöschl, U. (2020). Model calculations of aerosol transmission and infection risk of COVID-19 in indoor environments. *International Journal of Environmental Research and Public Health, 17*(21), 8114.	Nov 3, 2020	Modeling	Voice	Simulated office, classroom, choir practice, party	This modelling study estimates aerosol transmission of COVID-19 in several settings, including a choir practice, with various ventilation rates. Compared to other settings, choir practice was associated with highest likelihood of transmission.	Not appraised

Nusseck, M., Richter, B., Holtmeier, L., Skala, D., & Spahn, C. (2020). CO2 measurements in instrumental and vocal closed room settings as a risk reducing measure for a coronavirus infection. *Preprint*.	Oct 27, 2020	Aerosol emission	Voice, wind instruments: flute, recorder, clarinet, saxophone, oboe, brass instruments	Classroom	CO_2 concentration was used as a measure of indoor air quality. Contaminated indoor air is considered to be a factor in the transmission of COVID-19. CO_2 emissions during singing and wind instrument music lessons and associated duration of ventilation breaks were measured to determine possible duration of lessons before a critical level of 800ppm was reached, and a ventilation break would be required. Voice and wind instrument lessons were compared to a control group where participants spoke without playing an instrument. Ventilation was assessed using a CO_2 sensor. Wind instruments yielded significantly higher CO_2 emissions than the control group. Singing yielded lower CO_2 emission rates than the control group. Higher CO_2 emission rates were found in larger rooms. The duration of the lesson until the CO_2 concentration reaches the critical level of 800ppm in a $75m^3$ ranges between 25 minutes for the brass group and 36 minutes for the vocal and the control group. In a room of $100m^3$ the range of duration increases up to 35 minutes for the brass group and 53 minutes for the vocal and the control group. Ventilation (opening doors and windows) of 10 minutes was effective a reducing the CO_2 level in the room to outdoor levels, and is recommended between indoor lesson periods.	Not appraised ***PREPRINT***

Timmons Sund, L., Bhatt, N. K., Ference, E. H., Kim, W., & Johns, M. M., 3rd. (2020). Respiratory particle emission during voice assessment and therapy tasks in a single subject. *Journal of Voice*. Epub ahead of print.	Oct 22, 2020	Aerosol emission	Voice	Clinical (voice therapy room)	Respiratory particle emissions of 0.3-10μm were measured during singing and speaking exercises while wearing or not wearing a surgical mask. At short range (15cm), an unmasked person emits an average of 5.1 additional particles above baseline ambient levels. At a 1m range, there were no additional particles above baseline for a masked or unmasked person. In all conditions, there was no significant accumulation of particles. Limitations of this study include limited generalizability due to only one study subject being observed. Furthermore, this study only measured particles from 0.3-10μm, whereas human respiratory particles may range from 0.3-1000μm.	Not appraised
Moore, T. R., & Cannaday, A. E. (2020). Do "brassy" sounding musical instruments need increased safe distancing requirements to minimize the spread of COVID-19? *Journal of the Acoustical Society of America*, *148*(4), 2096.	Oct 15, 2020	Aerosol emission	Wind instruments: trumpets, trombones	Laboratory	Dispersion of particles of 15-50μm from the bells of trumpets and trombones were measured. Very little dispersion of particles was noted, with a maximum dispersion of 10cm from the bells of both instruments. Experiments were conducted in a controlled environment. It is unknown whether these results hold true in a performance setting.	Not appraised

Bahl, P., de Silva, C., Bhattacharjee, S., Stone, H., Doolan, C., Chughtai, A. A., & MacIntyre, C. R. (2020). Droplets and aerosols generated by singing and the risk of COVID-19 for choirs. *Clinical Infectious Diseases*. Epub ahead of print.	Sep 18, 2020	Aerosol emission	Voice	Not specified	Aerosol and droplet dispersion velocities during singing, speaking, and coughing was visually observed and measured. Maximum velocity of droplets expelled during singing was similar to those reported for speaking: 90% of droplets moved at velocities less than 1 m/s, and 75% of droplets moved at less than 0.5 m/s. This study did not investigate loudness, pitch, rhythm, or diction, which could impact results.	Not appraised
Mürbe, D., Kriegel, M., Lange, J., Schumann, L., Hartmann, A., & Fleischer, M. (2020). Aerosol emission of child voices during speaking, singing and shouting. *Preprint*.	Sep 18, 2020	Aerosol emission	Voice: 4 semi-professional child singers	Laboratory	Respiratory particle emissions by children of 0.3-25µm during singing, speaking, and shouting was measured. Four girls and four boys aged 13-15 years who had not undergone puberty vocal changes were tested. Emission rates for shouting were highest (683-4332 particles per second), followed by singing (141-1240 particles per second) and speaking (16-267 particles per second).	Not appraised ***PREPRINT***

He, R., Gao, L., Trifonov, M., & Hong, J. (2020). Aerosol generation from different wind instruments. *Journal of Aerosol Science, 151*, 105669.	Sep 16, 2020	Aerosol emission	Wind instruments: trumpet, bass trombone, French horn, tuba, flute, piccolo, bassoon, oboe, clarinet, and bass clarinet	n=15 professional musicians Controlled environment	Generation of aerosols of 0.5-20μm from brass and woodwind instruments being played at varying volumes and with different articulations was measured and compared to aerosol generation while breathing and speaking. Inferences on the risk of aerosol concentration for each instrument were drawn. Aerosol generation varied across instruments: tuba produced fewer aerosols than normal breathing; piccolo, flute, bass clarinet, french horn, and clarinet produced the same range of aerosols as normal breathing and speaking; and trumpet, oboe, and bass trombone generated more aerosols than speaking. Breathing produced fewer aerosols than speaking. Risk of aerosol production is found to be related to instrument size and mouthpiece design: • Brass instruments: aerosol concentration is found to be inversely correlated to tube length of the instrument. Aerosol concentration can be ranked as: trumpet > bass trombone > French horn > tuba • Woodwinds: aerosol production is inversely correlated to instrument size and is affected by mouthpiece design (i.e., air jet, single reed, and double reed instruments). Aerosol concentration can be ranked as: oboe > clarinet > bass clarinet > flute = piccolo > bassoon Aerosol generation relative to volume varied across instruments, with some exhibiting positive correlations between	Not appraised

					volume and aerosol generation (e.g., oboe, bassoon, clarinet), some exhibiting inverse correlations (e.g., flute, piccolo), and some not exhibiting a clear correlation (e.g., clarinet, trumpet, bass trombone, French horn). This study investigated instruments typically found in an orchestra. It is unknown whether these results are transferable to other wind instruments.	
Alsved, M., Matamis, A., Bohlin, R., Richter, M., Bengtsson, P. E., Fraenkel, C. J., ... Löndahl, J. (2020). Exhaled respiratory particles during singing and talking. *Aerosol Science and Technology*, *54*(11), 1245-1248.	Aug 24, 2020	Aerosol emission	Voice: 7 professional singers and five amateurs	Laboratory	Aerosol and particle emissions of 0.5-10μm during singing and talking at loud and normal volumes were measured. Singing at a normal volume produced significantly more particles than speaking at a normal volume. A trend towards more particles produced at higher pitches was noted. Professional singers produced two times more particles than amateur singers. The results are not significant. Results were measured for singing at set pitches. It is unknown how these results translate to singing songs in different musical styles.	Not appraised

Gregson, F.K.A., Watson, N. A., Orton, C. M., Haddrell, A. E., McCarthy, L. P., Finnie, T. J. R., … Reid, J. P. (2020). Comparing the respirable aerosol concentrations and particle size distributions generated by singing, speaking and breathing. *Preprint*.	Aug 20, 2020	Aerosol emission	Voice: 25 professional singers	Laboratory (operating theatre)	Aerosol and droplet concentration during breathing, coughing, speaking, singing a single note and singing a song were measured at close range (10cm). Comparisons between genders and across different singing genres (e.g., opera, theatre) were drawn. On average, singing generated a significantly higher concentration of aerosols than speaking. Singing and speaking at low volumes did not yield statistically significantly different aerosol concentrations than breathing. No significant difference in aerosol production between genders or across singing genres was found.	Not appraised ***PREPRINT***
Parker, A. S., & Crookston, K. (2020). Investigation into the release of respiratory aerosols by brass instruments and mitigation measures with respect to COVID-19. *Preprint.*	Aug 4, 2020	Aerosol emission	Brass instruments: cornet, tenor horn, baritone horn, euphonium, trombone, Eb tuba, Bb tuba Professional musicians	Laboratory	Aerosol (<5μm) and droplet (>5μm) emissions from seven brass instruments compared to normal breathing were measured. On average, fewer aerosol particles were produced while playing than while breathing. Conversely, more droplets were produced while playing than while breathing.	Not appraised ***PREPRINT***

Becher, L., Gena, A. W., & Bauhaus, C. V. (2020, Jul 23). Risk assessment of the spread of breathing air from wind instruments and singers during the COVID-19 pandemic.	Jul 23, 2020	Aerosol emission	Wind instrument: oboe, bassoon, Bb clarinet, bass clarinet, flute, piccolo, soprano recorder, Bb trumpet, tenor trombone, French horn, tuba. Voice: baritone (adult male), soprano (adult female)	Laboratory	The maximum distance of aerosol emissions from singing and playing a wind instrument was measured. Maximum distance for each instrument and singer was measured for wind instruments ranging from 20-100+cm, and singing ranging from 60-90cm. How these results differ between players or playing styles was not explored.	Not appraised ***NOT PEER REVIEWED***
Hartmann, A., Mürbe, D., Kriegel, M., Lange, J., & Fleischer, M. (2020, Jul 22). Risk assessment of rehearsal rooms for choir singing regarding aerosols loaded with virus. *Preprint.*	Jul 22, 2020	Modeling	Voice	Rehearsal room, concert hall	This modelling study estimates aerosol transmission of COVID-19 in choir practice and concert settings (with assumptions of a populated concert space) over time. Compared to an office setting, • The estimated concentration of aerosols in concert halls was lower • The estimated concentration of aerosols in a rehearsal room was higher Overall, the risk of aerosol transmission was estimated to be lower in larger, concert hall settings.	Not appraised ***PREPRINT***

Eiche, T. (2020). Studies on aerosol emissions by speaking, singing as a choir or solo, and playing wind instruments. *Preprint*.	Jun 26, 2020	Aerosol emission	Wind instruments: Bb clarinet, Eb clarinet, bass clarinet, oboe, oboe d'amore, flute, piccolo, bassoon, contrabassoon, trombone, Horn, trumpet, tuba Voice Professional musicians	Rehearsal room, theatre stage	Respiratory particle concentrations during breathing, singing, speaking, screaming, and playing wood and brass instruments were measured. Variation between people varied significantly; however, certain patterns emerged: • Less aerosols were produced while playing wind instruments than while speaking • There was very little difference in particle emissions when singing loudly compared to singing quietly • There is a positive correlation between particle concentrations and the loudness/expressiveness of speech The results of this study are limited in that the smallest particle measured was 0.25µm, whereas the SARS-CoV-2 virus is 0.1µm. Therefore, risk of COVID-19 transmission cannot be inferred from the results of this study.	Not appraised ***PREPRINT***
Brandt, L. (2020). Measurement of aerosol from brass and woodwind instruments playing 5 minutes in distances from 0.5 to 4 meter.	2020	Aerosol emission	Wind instruments: tuba, clarinet, trombone, bassoon, oboe, trumpet, horn, flute	Rehearsal room	Concentration of airborne particles of 1, 2.5 and 10µm emitted from brass and woodwind instruments at 0.5, 1, 2, 3 and 4m was measured and compared to background levels and coughing. At all distances, particle concentrations for tuba, clarinet, and trombone were similar to background concentration measures. Particle concentrations for bassoon, oboe, trumpet, horn and flute were slightly higher than background levels. In contrast, coughing yielded particle levels 70,000 times higher than background levels.	Not appraised ***NOT PEER REVIEWED***

Table 3: In progress Single Studies

Title	Anticipated Release Date	Instruments	Description of Document
Berghöfer, A. (2020). Prospective cohort study on the incidence of SARS-CoV-2-infections (COVID-19) in professional orchestra musicians and choir singers.	Not stated	Wind instruments, voice	This prospective cohort study will determine the incidence of SARS-CoV-2 infections in orchestra musicians, choir members, and non-musician controls employed in concert and opera houses.
Veeraraghavan, A., Yekovich, R., Mangum, J., Farrell, S., Raghuram, A., & Boominathan, V. (2020). Tunesflow: Studying aerosol flow spread for wind instruments and singing.	Not stated	Wind instruments, voice	This study will visualize the aerosol propagation from orchestra musicians (via woodwind and brass instruments) and opera singers using high-speed contrast imaging.

Question 2: What strategies are effective at minimizing risk of transmission during musical activities?

Table 4: Syntheses

Reference	Date Released	Description of Included Studies	Summary of Findings	Quality Rating: Synthesis	Quality Rating: Included Studies
Public Health Ontario. (2020, Nov 18). COVID-19 Transmission from Singing and Playing Wind Instruments: What We Know So Far.	Nov 18, 2020 (Search completed Oct 26, 2020)	This updated rapid review added 22 new studies to an unspecified total: • 10 experimental • 4 observational • 2 review • 6 grey literature reports	Transmission risk may be minimized by: • Physical distancing • Mask use (when possible) • Proper hand hygiene • Avoiding sharing equipment or materials • Larger venues • Routine surface cleaning • Shortened performances • Optimal ventilation or outdoor venue It is not clear whether these strategies were proven effective in the included studies or only examples of what has been attempted.	Low	Not reported ***NOT PEER REVIEWED***

National Collaborating Centre for Environmental Health. (2020, Sep 23). COVID-19 Risks and precautions for the performing arts.	Sep 23, 2020 (Search date not provided)	This rapid review included 21 media and literature reports of COVID-19 clusters and outbreaks associated with singing, dance, theatre, and bands.	Transmission risk may be minimized by: • Screening • Forming performance or rehearsal cohorts (i.e., to limit interaction within larger companies) • Physical distancing (particularly during rehearsals, instruction, socialization, backstage preparation) • Larger venues, with multiple entrances • Reduced audience density • Shortened performances (e.g., 30-minute limits) • Mask use (however, the effectiveness of specialized "singers' masks" and face shields has not been assessed) • Optimal ventilation or outdoor venues • Proper hand hygiene • Routine cleaning and disinfection of surfaces • Avoid sharing equipment • Offsite preparation (hair, makeup) A limitation is the lack of epidemiological evidence to confirm these observations.	Low	Not reported ***NOT PEER REVIEWED***
Public Health Agency of Canada (2020, Jul 5). Emerging Evidence on COVID-19: COVID-19 Summary of SARS-CoV-2 Transmission and Singing/Wind Instruments.	Jul 5, 2020 (Search completed Jun 26, 2020)	This evidence brief included: • 5 experimental and simulation studies • 4 mathematical models • 5 published epidemiological investigations • 7 reports from the grey literature	There is no conclusive evidence of effective mitigation strategies for musicians.	Low	Range from high risk of bias and low quality (empirical evidence) to moderate/high quality (simulation and model studies) ***NOT PEER REVIEWED***

National Collaborating Centre for Environmental Health. (2020, Jul 1). COVID-19 Risks and Precautions for Choirs.	Jul 1, 2020 (Search date not provided)	This rapid review included media reports and limited published evidence (study design not described).	Transmission risk via large respiratory droplets may be minimized by: • Mask wearing • Respiratory etiquette (e.g. covering mouth when coughing or sneezing) • Physical distancing, including backstage and staggered arrangement on stage Transmission risk via respiratory aerosols may be minimized by: • Reducing crowding • Reducing duration of indoor interactions • Ensuring proper ventilation • Avoiding face-to-face singing Transmission risk via contact transmission and fomites may be minimized by: • Proper hand hygiene • Routine surface cleaning and disinfection • Avoiding sharing equipment, food, and drink Transmission risk from pre-symptomatic and asymptomatic persons may be minimized by: • Self-isolating persons who have tested positive for COVID-19 or have been exposed to known cases • Limiting number of social contacts, restricting group sizes • Physical distancing • Mask wearing	Low	Not reported ***NOT PEER REVIEWED***

Alberta Health Services. (2020, May 22). Topic: Singing as a risk for transmission of SARS-CoV-2 virus.	May 22, 2020 (Search date not provided)	This rapid review included: • 2 epidemiological reports • 5 epidemiological studies* • 1 primary study* *3 epidemiological studies and 1 primary study analyzed other infectious diseases, not COVID-19, specifically	Transmission risk may be minimized by: • Restricting singing in group settings, especially indoors • Social distancing • Proper hand hygiene before and after • Masking, when distancing not possible • Individuals with respiratory symptoms refrain from joining The authors recommend that, if public health restrictions begin to be reduced, restrictions on singing should not be lifted in the first round(s), until new evidence emerges.	Low	Low (for one study; quality of other included studies not reported) ***NOT PEER REVIEWED***

Table 5: Single Studies

Reference	Date Released	Study Design	Instruments	Setting	Summary of findings	Quality Rating:
Narayanan, S. R., & Yang, S. (2021). Airborne transmission of virus-laden aerosols inside a music classroom: Effects of portable purifiers and aerosol injection rates. *Preprint*.	Jan 3, 2021	Modeling	Brass instruments (trombone, trumpet); voice	Classroom	This modelling study estimates aerosol transmission of COVID-19 in a music class with various air purifiers, with and without mask-wearing. Singing with or without a mask produced more aerosols than playing a brass instrument. Using an air purifier reduced aerosols, with removal of 97% after a 25-minute break period.	Not appraised ***PREPRINT***
Abraham, A., He, R., Shao, S., Kumar, S. S., Wang, C., Guo, B., … Hong, J. (2020). Risk assessment and mitigation of airborne disease transmission in orchestral wind instrument performance. *Preprint.*	Dec 24, 2020	Aerosol emission	Wind instruments	Concert Hall	Researchers tested aerosol emissions from brass and woodwind instruments while using a bell cover and while using air filters to mitigate spread. For trumpet, a 3-layer cover is sufficient to reduce particle concentration to 10% of initial value. However, the 3-layer cover was "close to unplayable," suggesting that while this type of cover is efficacious, it may not be a feasible solution. For trumpet, an air filter placed above the musician removed 90% of aerosols; comparably, an air filter placed on the floor in front of the musician only removed 3% of aerosols. Other brass and woodwind instruments not explored.	Not appraised ***PREPRINT***

Colorado State University. (2020, Dec 2). *Reducing Bioaerosol Emissions and Exposures in the Performing Arts: A Scientific Roadmap for a Safe Return from COVID19*.	Dec 2, 2020	Aerosol emission	Wind instruments, voice	Laboratory	Preliminary results of dispersion of aerosols in singers while singing with and without masks and while playing instruments with and without a cover are presented. Authors note that masks and instrument covers reduce aerosol dispersion but do not provide levels or context.	Not appraised ***NOT PEER REVIEWED***
Lelieveld, J., Helleis, F., Borrmann, S., Cheng, Y., Drewnick, F., Haug, G., ... Pöschl, U. (2020). Model calculations of aerosol transmission and infection risk of COVID-19 in indoor environments. *International Journal of Environmental Research and Public Health, 17(*21), 8114.	Nov 3, 2020	Modeling	Voice	Simulated office, classroom, choir practice, party	This modelling study estimates aerosol transmission of COVID-19 in several settings, including a choir practice, with various ventilation rates. Risk was most reduced when high-volume ventilation with a HEPA filter was used. This model did not explore the effect of mask-wearing during choir practice.	Not appraised
Nusseck, M., Richter, B., Holtmeier, L., Skala, D., & Spahn, C. (2020). CO2 measurements in instrumental and vocal closed room settings as a risk reducing measure for a coronavirus infection. *Preprint*.	Oct 27, 2020	Aerosol emission	Voice, wind instruments: flute, recorder, clarinet, saxophone, oboe, brass instruments	Classroom	CO_2 concentration was used as a measure of indoor air quality. Contaminated indoor air is considered to be a factor in the transmission of COVID-19. The duration of the lesson until the CO_2 concentration reaches the critical level of 800ppm in a 75m^3 ranges between 25 minutes for the brass group and 36 minutes for the vocal and the control group. In a room of 100m^3 the range of duration increases up to 35 minutes for the brass group and 53 minutes for the vocal and the control group. Ventilation (opening doors and windows) of 10 minutes was effective a reducing the CO_2 level in the room to outdoor levels and is recommended between indoor lesson periods.	Not appraised ***PREPRINT***

Alsved, M., Matamis, A., Bohlin, R., Richter, M., Bengtsson, P. E., Fraenkel, C. J., ... Löndahl, J. (2020). Exhaled respiratory particles during singing and talking. *Aerosol Science and Technology*, *54*(11), 1245-1248.	Aug 24, 2020	Aerosol emission	Voice: 7 professional singers and five amateurs	Laboratory	Aerosol and particle emissions of 0.5-10µm during loud singing with and without a surgical mask was measured. Singing loudly with a surgical mask reduced aerosol particles to a level similar to speaking at a normal volume.	Not appraised
Parker, A. S., & Crookston, K. (2020). Investigation into the release of respiratory aerosols by brass instruments and mitigation measures with respect to COVID-19. *Preprint.*	Aug 4, 2020	Aerosol emission	Brass instruments: cornet, tenor horn, baritone horn, euphonium, trombone, Eb tuba, Bb tuba Professional musicians	Laboratory	Aerosol (<5µm) and droplet (>5µm) emissions from seven brass instruments with and without cotton barriers over the bell were compared. Playing with a barrier reduced particle emissions compared to playing without. Aerosol production was reduced by 78.5% and droplet production was reduced by 63.8%.	Not appraised ***PREPRINT***
Eiche, T. (2020). Studies on aerosol emissions by speaking, singing as a choir or solo, and playing wind instruments. *Preprint*.	Jun 26, 2020	Aerosol emission	Wind instruments: Bb clarinet, Eb clarinet, bass clarinet, oboe, oboe d'amore, flute, piccolo, bassoon, contrabassoon, trombone, Horn, trumpet, tuba Voice Professional musicians	Rehearsal room, theatre stage	Physical distancing and room ventilation as protective measures against respiratory particle concentrations during breathing, singing, speaking, screaming, and playing wood and brass instruments were explored. Aerosols were detected at up to 4m for wind instruments and 7m for opera. However, no accumulation of particles was noted. The authors speculate that the lack of accumulation was attributed to the large size of the rooms and the continuous ventilation. The results of this study are limited in that the smallest particle measured was 0.25µm, whereas the SARS-CoV-2 virus is 0.1µm. Therefore, risk of COVID-19 transmission cannot be inferred from the results of this study.	Not appraised ***PREPRINT***

Table 6: In-progress Single Studies

Title	Anticipated Release Date	Instruments	Description of Document
Sala, B. C., Codina, J. M. L., Barriga, B. R., Tabuenca, L. R., Guillermo, I. B., Ortiz, A. A., & Deiros, R. P. (2020). Risk of infection of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), COVID-19, in a massive musical show with transmission prevention measures.	Dec 22, 2020	Music event	This randomized study will test the ability of rapid screening to identify asymptomatic infection in people attending a large music event.
Veeraraghavan, A., Yekovich, R., Mangum, J., Farrell, S., Raghuram, A., & Boominathan, V. (2020). Tunesflow: Studying aerosol flow spread for wind instruments and singing.	Not stated	Wind instruments, voice	This study will visualize aerosol production from orchestra musicians (via woodwind and brass instruments) and opera singers using high-speed contrast imaging. It will make recommendations for designing safe performance spaces, based on study outcomes.

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Alsved, M., Matamis, A., Bohlin, R., Richter, M., Bengtsson, P. E., Fraenkel, C. J., … Löndahl, J. (2020). Exhaled respiratory particles during singing and talking. *Aerosol Science and Technology*, *54*(11), 1245-1248.

Bahl, P., de Silva, C., Bhattacharjee, S., Stone, H., Doolan, C., Chughtai, A. A., & MacIntyre, C. R. (2020). Droplets and aerosols generated by singing and the risk of COVID-19 for choirs. *Clinical Infectious Diseases*. Epub ahead of print.

Becher, L., Gena, A. W., & Bauhaus, C. V. (2020, July 23). Risk assessment of the spread of breathing air from wind instruments and singers during the COVID-19 pandemic.

Berghöfer, A. (2020). Prospective cohort study on the incidence of SARS-CoV-2-infections (COVID-19) in professional orchestra musicians and choir singers.

Brandt, L. (2020). Measurement of aerosol from brass and woodwind instruments playing 5 minutes in distances from 0.5 to 4 meter.

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Gregson, F.K.A., Watson, N. A., Orton, C. M., Haddrell, A. E., McCarthy, L. P., Finnie, T. J. R., … Reid, J. P. (2020). Comparing the respirable aerosol concentrations and particle size distributions generated by singing, speaking and breathing. *Preprint*.

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