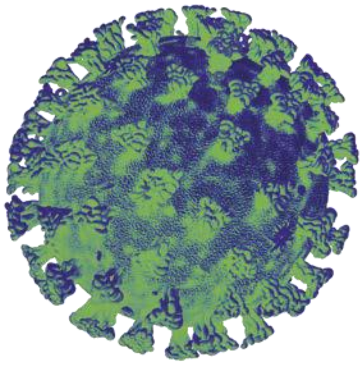
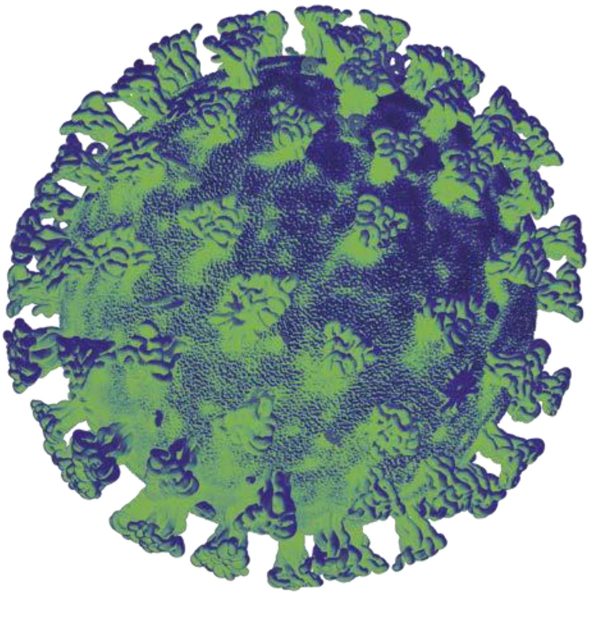
Llywodraeth Cymru
Welsh Government

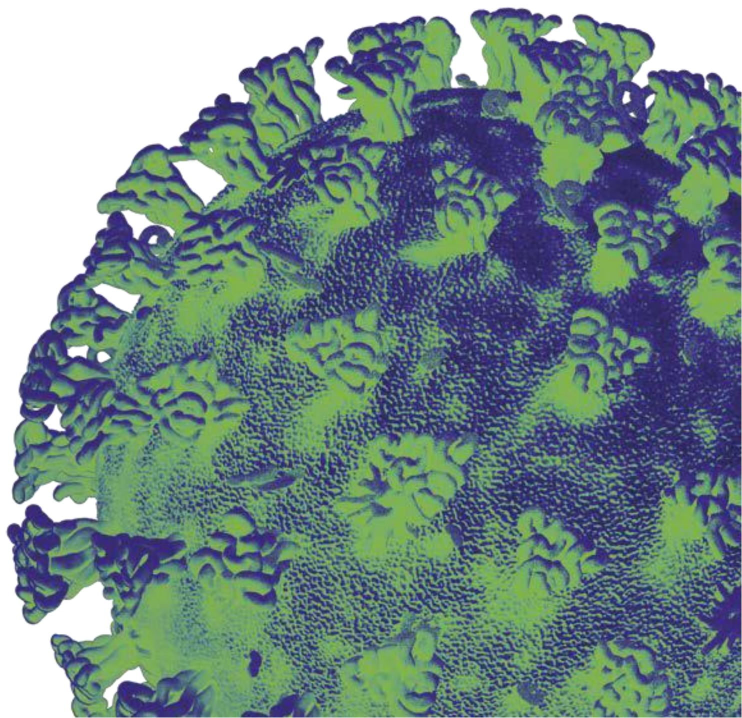
Technical Advisory Group

Review advice on communal singing and chanting, including blowing of wind instruments and pipe organs.

June 2021







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Summary

Across the UK, 2.1 million people regularly sing and there are 70,000 choirs, of which ca.90% are associated with faith and school groups. This paper updates the review on singing undertaken by TAG-E in November 2020. It summarises the latest evidence pertaining to the risk of disease transmission in relation to singing, vocalisation and musical performance. It concludes that there is very clear evidence that indoor communal singing (e.g. choirs) in the absence of any mitigation measures (NPIs) can result in the superspreading of COVID-19. Consequently, these events pose high risk if no mitigation measures are used, particularly when there are high levels of COVID-19 circulating in the population. Conversely, there is no evidence that outdoor singing leads to disease superspreading.

Although studies are limited, the risk of viral aerosol generation appears to be significantly lower in children relative to adults, suggesting that singing and musical performances in under 18-year olds pose a lower risk. The risk of viral emission during the playing of musical instruments also appears to be much lower than that of singing, while the role of church pipe organs in aerosol generation appears negligible.

There is compelling evidence that vocalisation by an infected individual will result in the projection of droplets containing virus into the environment, underlining the importance of infected individuals avoiding communal gatherings. What happens once they get there – and the relative risk to others – will depend on a number of environmental and mitigating factors.

Standard mitigation measures (NPIs) should be used to reduce disease transmission risk during communal singing events (e.g. social distancing, use of face covering, hand hygiene, routine cleaning and disinfection of surfaces). However, the benefits of some mitigation options still remain inconclusive or unproven (e.g. use of air purifiers, plastic shielding).

We also highlight potential areas for future work to enable to design of more effective and targeted mitigation measures.

In summary, when the incidence of SARS-CoV-2 circulating in Wales is low, then both indoor and outdoor singing-related activities should pose a very low risk, particularly if the mitigation strategies highlighted here are implemented. However, this should be regularly reviewed in light of the potential for the emergence of vaccine-escaping or more transmissible variants of SARS-CoV-2.

Introduction

The COVID-19 pandemic, caused by SARS-CoV-2, poses a number of challenges for organisations to prevent the spread of infection in indoor environments in particular. Respiratory particles in the form of both droplets and aerosols exist in human exhaled breath, and activities such as speaking loudly, singing, sneezing and coughing will result in greater aerosol generation. Some studies suggest singing may result in a 20-30 fold increase in particle generation [1,2] while loudness of speaking or singing is also important in determining the amount of aerosol emitted [2,3].

This paper simply covers the environmental aspect of singing and so other areas such as wellbeing etc. are out of scope. This subject is complex with a many facets to consider, coupled with the science around these issues is still evolving and will be continuously evolving.

Infected individuals shed the virus prior to the onset of symptoms, meaning that focusing on symptoms as a basis for preventing infection is not sufficient to prevent transmission even if everyone follows self-isolation rules. Significant transmission is known to take place while patients are pre-symptomatic [6,7]. There is also compelling evidence that a significant proportion of cases (ca. 30%) are asymptomatic or pauci-symptomatic [8,9,59]. This means that strategies for control of the virus should include measures that reduce the probability of infected individuals who are a- or pre-symptomatic from infecting others, which requires an understanding of the risks of activities which may by their nature increase the opportunities for transmission between individuals.

In particular, there has been recent interest in the risks associated with activities involving vocalisation or voice projection, which may pose a risk for increased transmission in both indoor and outdoor environments.

This paper summarises the latest evidence investigating this area for SARS-CoV-2 specifically, as well as drawing on some evidence from other respiratory pathogens relating to additional aspects that should be considered and examined. We also include a summary of similar evidence synthesis activities undertaken by other health agencies around the world for reference.

Scope

This paper is concerned with collecting the evidence relating to the risks of transmission through a specific set of activities. These activities are particularly relevant to a number of settings including those associated with performance (theatres, live music), schools and places of worship. This paper does not cover the other impact of live performances. It should be noted that there are a wide range of factors that will impact the likelihood of transmission associated with a specific activity in a specific place, and this is an area where research is still being conducted. Therefore, the evidence and our conclusions may change over time. Also please note that this paper presents evidence, not advice.

Scientific evidence

Evidence for COVID-19 in relation to singing and chanting

SARS-CoV-2 may be transmitted to a large amount of individuals simultaneously during so-called ‘superspreading events’ [10,11,60,61]. Superspreading events do not happen often, but they are important. For example, in New Zealand superspreading was found to be a significant contributor to the epidemic dynamics, with 20% of cases among adults responsible for 65-85% of transmission [63]. This is consistent with the behaviour of other coronaviruses [12,13], and on a practical level points towards the fact that certain activities and behaviours carry a higher risk, as they may provide an opportunity for a large amount of transmission to take place within a group of individuals, in a single place [62, 64]. It is important that as part of control measures, the potential of certain activities to enable superspreading events is understood, in order to support effective prevention [14]. Over the course of the SARS-CoV-2 pandemic so far, superspreading events have been linked to a variety of environments or events – from social gatherings (e.g. weddings, karaoke bars, community choirs) to workplaces.

Global efforts are underway to undertake research associated with superspreading events, and a number of activities are being undertaken to map reports of superspreading events globally. Efforts to collate reports of superspreading events provide an indication of the potential importance of activities where a ‘vocal’ element may play a role in transmission. Although many of these efforts are not systematic, they are instructive and point to specific examples which illustrate potential risks associated with certain activities. In an international database of reported superspreading events, 256 of the 2044 entries mark the event as being related to ‘vocalisation’ encompassing an estimated 50,916 cases [15]. Of these, 18 events were associated with choir practices or recitals, 3 were associated with concerts, 17 with weddings while an additional 38 were associated with other religious activities. Another study in the Netherlands tracing COVID-19 transmission at six singing events reported a high attack rate ranging from 25–74% [74].This is similar to a study in the USA following a cohort of 61 persons after a 2.5-hour choir practice attended by an infected individual where the attack rate was estimated at 53 to 87% [17].

Across the UK, 2.1 million people regularly sing and there are 70,000 choirs, of which ca.90% are associated with church and school groups. These vary in size from 4 to 700 people. All the available evidence suggests that singing and other forms of vocalisation louder than talking may carry an increased risk in disease transmission, however, this data is not systematically collected and the environmental factors that enhance viral transmission are multifaceted. Sharing of surfaces, lack of social distancing, poor ventilation, and sharing of food and drinks are also characteristic of such events, all associated with viral superspreading. It is also important to understand that while there may be evidence of an event/place being associated with a superspreading event, this is a correlation, and does not prove causation. In some cases, for example, transmission may occur between individuals prior to reaching the event (e.g. travelling to the venue). Moreover, by their nature analyses and investigations of superspreading events are retrospective. In many cases, SARS-CoV-2 sequencing is not undertaken to confirm the nature of the outbreak (i.e. to estimate the number of infected individuals present and that the virus was contracted at the event)[74]. This complexity, combined with limited scientific evidence creates significant uncertainty, which poses a challenge for policy makers and for the public.

While there is uncertainty around the absolute risk of superspreading events associated with activities involving singing, the scientific literature includes several reported outbreaks have been associated with choirs [16,17,74] and live events [18,19,20]. However these are small numbers compared with the likely exposure to such events. Recent experimental work to visualise aerosol and droplet generation during singing also indicates that loudness and direction and velocity of aerosol could pose a risk to those in a choir, especially where there is inadequate ventilation and no social distancing [21,22,76].

While the specific work to understand the basis of superspreading in SARS-CoV-2 is evolving, there has been significant work to systematically examine factors/behaviours that could increase transmission risk. Based on current scientific evidence we have very high confidence that:

- Infectious particles are present in exhaled breath, and these can vary in size. While the dynamics of the largest droplets are dominated by gravitational effects, the smaller aerosol particles, mostly transported by means of hydrodynamic drag, form clouds that can remain afloat for long period of time [23,24,65]. Smaller aerosols may carry more viral load than larger droplets since they originate from deep within the respiratory tracts where there is more viral concentration[68]. Several studies have reported that for singing, particle dimensions are centred around 0.5 to 2 μm while for speaking it is 0.8 to 1 μm[71]. For droplets larger than 1 μm, gravity becomes more significant than Brownian motion in deciding the fate of such particles (Table 1)[77]. However, droplets smaller than 100 μm often evaporate before reaching the ground and thus linger in the air for prolonged periods. These viral particles may remain viable for several hours[77,78]. While virus transmission via droplets can be mainly handled by distance and hygiene rules, the risk management of transmission through virus carrying aerosols has to be addressed with further strategies (e.g. ventilation, air purifiers).

Table 1. Droplet falling time as a function of size[77]

Droplet diameter (μm)	Falling time of 1 m (s)
1000	0.3
100	3
10	300
1	30,000

- Activities involving speaking, singing or exhaling breath forcibly result in greater aerosol or droplet generation [1,2]. Generally, the emission of viral particles from individuals follows the series cough > singing > speaking > breathing (Fig. 2)[73].
- The louder/more sustained the activity, the more aerosol or droplets are generated [1,25]. At quiet volumes (50 to 60 dBA), neither singing nor speaking were seen to be significantly different to breathing in terms of viral emission risk[72]. The spatial pattern of the aerosol clouds formed during singing is complex and varies depending on the loudness of singing/vocalisation, vocal technique and lung capacity, and the positioning of the head[22], as well as wearing of a face covering. The aerosol cloud can travel behind the singer. This spatial spread is also greatly influenced by ventilation.
- The amount and infectivity of virus emitted by an individual varies, depending on a number of factors including their age, size, stage in the infection cycle, SARS-CoV-2 lineage etc (Fig. 2) [3,25].
- Some individuals can be super-emitters [3].
- Although not experimentally tested to date, communal chanting (speaking in a quiet voice) is likely to be very similar to breathing in terms of viral emissions (i.e. very low risk).

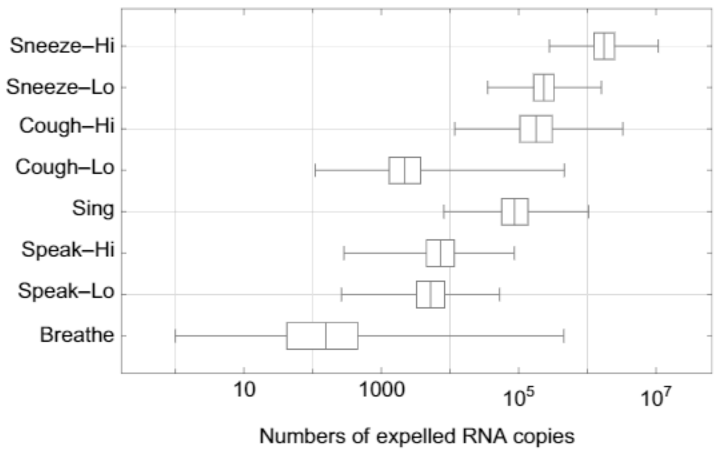

Fig. 1. *Measured particle emission rates from adolescents and adults during three different vocalisation scenarios* [71].

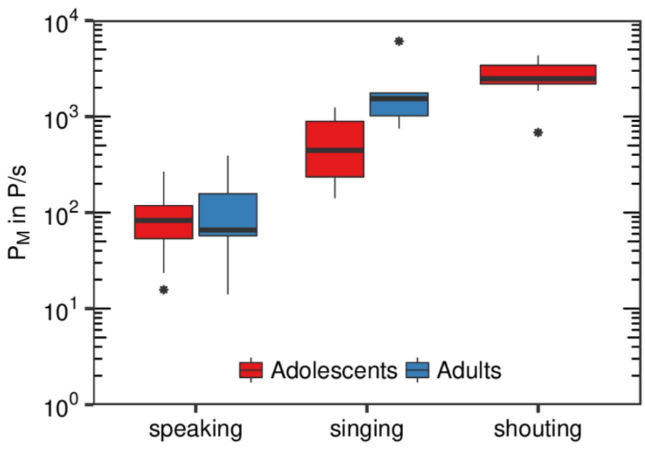

***Fig. 2**. Box-and-whisker chart showing the total number of viral copies expelled during 20 min of breathing, speaking, or singing, and after one cough or one sneeze; Lo and Hi denote low and high aerosol volume relative to each other [73].*

In essence, there is compelling evidence that vocalisation by an infected individual will result in the projection of droplets containing virus into the environment. What happens once they get there – and the relative risk to others – will depend on a number of environmental factors. Specifically, environmental aspects that may increase risk of transmission include:

- Lack of social distancing (identified as a factor in [18,19,20])
- Insufficient ventilation at indoors venues (identified as being important to reduce transmission in a number of environments [26-30])
- Temperature (environments below 15^{o}C have been identified as contributing to transmission potential and environmental survival [31–33])
- Humidity (Droplet dispersal, environment survival and transmission shows a complex relationship with relative humidity. The evidence base is still not clear as different humidities appear to differentially affect survival and dispersal in the air and on surfaces [34–37, 65, 80, 81])
- Whether the activity is undertaken indoors or outdoors. As yet, no outdoor superspreading events associated with singing have been identified.

Other factors that have been identified as affecting risk of transmission include (in no specified order):

- Duration of performance (longer duration equals higher risk) [38, 83]
- Number of singers (more singers potentially equates to higher risk) [38]
- Audience behaviour (e.g. singing along by the audience) [38]
- Audience density (early outbreaks in music venues were partly linked to the density of the audiences[20], and this potential risk is obvious based on what is understood from social distancing elsewhere in society [39])
- Age of singers. Adolescents emit fewer aerosol particles during singing than what has been known so far for adults (Fig. 2) [71].
- Use of masks/visors/physical barriers (may reduce spread although while there is good evidence around masks and visors [39,40,41,75], physical barriers are much less well studied). It is also important to emphasise that visors alone are not recommended, as while they may provide protection to the wearer, they do not protect others [41].
- Nasal blockage due to COVID-19 related symptoms which enhances viral discharge from the mouth [66.]
- Whether individuals sneeze in which large droplets can carry up to 4 m [67].
- Times between events (e.g. break periods between music lessons) [68]
- Whether amplification is used to reduce singing intensity [72].
- The type of singing (i.e. classical vs. contemporary) has not been shown to greatly influence risk[75].

The relative importance of these 11 factors is difficult to quantitatively assess as there has been insufficient research to date. In particular, rarely are the interventions or factors directly compared in the same environmental setting. Thus, while we know that they are likely to be important, we have low confidence in evaluating their impact on viral transmission. In addition, their importance will be highly dependent on the size and configuration of the venue. The factors highlighted above represent ‘common sense’ and most publications that reference these are drawing a conclusion from the observed data, without an ability to formally analyse the data to prove a hypothesis. In addition, many publications use model simulations to predict the dispersal of droplets and aerosols within indoor settings [65]. These models have many uncertainties and in most cases have not been experimentally validated. Those that have been validated have not been done so with an actual virus, rather they have used proxies such as CO_2, temperature and aerosol particles.

Collectively, therefore, there are a significant number of variables in play, and any mitigation strategy should take a holistic view, which aims to identify all of the relevant risks for a given environment, and deploy mitigations for these.

Relevant evidence from other pathogens

As has been evidenced by a number of outbreak, certain environmental factors (low temperature, low humidity, noisy environments) appear to make transmission more likely [15,42,43]. While the evidence base around COVID-19 is still developing, the role of the environment is heavily researched and better understood for other respiratory pathogens. This is well understood in other organisms such as Influenza [37,39,44], but may pose challenges when considering the risk of transmission of SARS-CoV-2 as assessed in laboratory settings. In addition to work on Influenza, and although it is not a viral pathogen, TB may provide some further insight into potential risks for transmission in closed environments. A small number of TB outbreaks have been linked to singing [45,46,47,82], and the importance of ventilation in reducing the chances of TB transmission have been recognised for some time, with numerous studies demonstrating the importance of ventilation to reduce transmission (e.g. [47-50]). It should be noted, however, that inappropriately positioned ventilation has also promoted TB transmission within a choir setting [82].

Evidence in other pathogens emphasises the importance of environmental factors in enabling transmission. Within Wales, particular attention should be paid to buildings where singing, chanting and performance activities are to take place. Although the consensus is still developing, as seasons change it is particularly important that buildings that may be at risk of exposing audiences and performers to low temperatures (e.g. in buildings with ineffective heating) or low humidity (e.g. air conditioned environments), or poor ventilation (e.g. non opening windows) be properly risk assessed for transmission potential as part of any reopening. Unpredictable environmental factors or unique features of buildings may increase the risk of transmission above and beyond that which would be predicted based upon laboratory experimentation. Mitigation strategies for some of these issues may introduce other risks, and cause other harms.

Evidence for COVID-19 in relation to musical instrument playing

In August 2020, the SAGE Singing and Wind Instrument Group examined the current evidence relating to aerosol and droplet generation from singing, wind instruments and performance activities [22,51]. The Group commissioned two research trials (PERFORM and SOBADRA). Regarding the risk from droplets, these studies demonstrate that social distancing is the most important mitigation measure as droplet deposition generally does not extend beyond 2 metres, which is consistent with a more recent German study[22]. For aerosols, the Group recommended that social distancing **and** ventilation are important mitigation measures due to the potential aerosol transmission risk beyond 2 metres. Other work examining aerosol generation from wind instruments, and indicates that the concentration of aerosols generated by wind instruments can vary over 2 orders of magnitude, with the size of aerosols/droplets being generated also varying (Fig. 3). This evidence suggests that mitigation measures may need to vary based upon the instrument(s) being utilised [52,69]. Less skilled players may also pose a greater risk than professional performers due to the greater leakage of air [69]. Further, the movement of musicians will also affect the dispersal [69]. Overall, however, the risk is less than singing [75]. There is no evidence that pipe organs increase the dispersal of COVID-19 in places of worship and they should be considered low risk [79]. It should be noted that pipe organs are high pressure, low velocity devices and are frequently located away from other individuals.

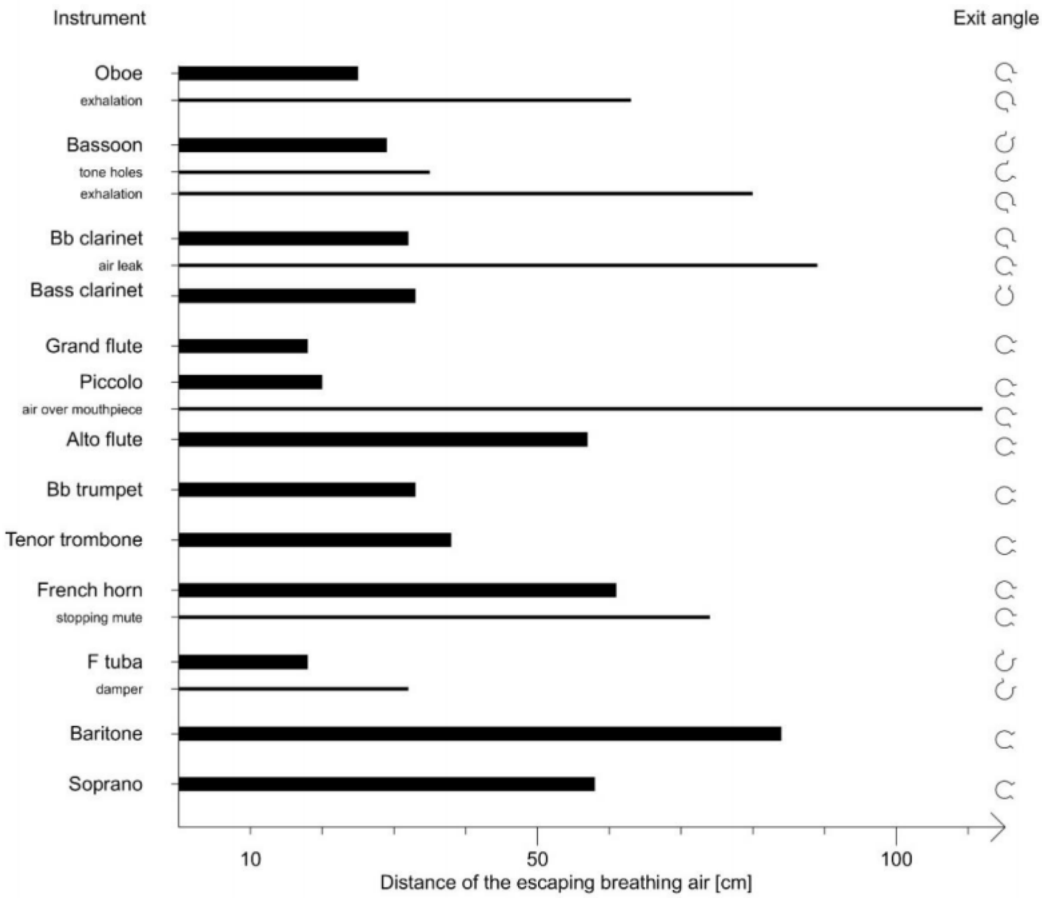

Fig. 3. Maximal spreading distance of the breathing air from wind instruments and singers [69].

Recommended mitigation options to reduce the risk of SARS-CoV-2 transmission during singing activities

Based on the evidence presented above, the risk of disease transmission during singing events is clearly dependent on (i) the type of event, (ii) the space in which the activity is taking place, (iii) the levels of COVID-19 circulating in the general population, (iv) the lineages of SARS-CoV-2 in circulation, and (iv) levels of vaccination and use of NPI measures Due to this, it is not possible to provide definitive guidance on all activities covered under ‘singing and vocalisation’. In addition, if there is an infected person present at an event it should be stated that the risk of transmission to others will never be zero. Rather, we provide general guidance for these activities. Based on current government guidance[53] and other evidence[54,55,56], suggested mitigation options to reduce the risk of COVID-19 transmission include:

1. As required by national guidance, people with symptoms suggestive of COVID-19, or who are known to have been in recent contact with others who have COVID-19, do not participate in singing or attend singing events.
2. Singing takes place only in larger well-ventilated spaces, or outdoors.

3. Face coverings should be worn where this is practicable. Singers' masks are available which are designed to hold the material away from the nose and mouth allowing normal vowel production and projection.
4. Performance or rehearsal is for limited periods of time at a reduced level of loudness, using microphones for amplification if available.
5. Limited numbers of people sing together. Communal chanting with face coverings should be in a quiet voice.
6. Singers are spaced at least 2 metres apart in all directions.
7. Audience, gatherings, observers and teachers are also spaced at least 2 metres from the singers or musicians.
8. Orientation of performers avoids face-to-face positioning.
9. Avoid sharing of written materials, microphones, sheet music, stands, books etc.,
10. Due consideration is also given to reducing transmission risk within the venue (hand hygiene, regular cleaning and disinfection of surfaces) and associated secondary activities (e.g. travelling to the venue, public toilets, socialising before, during and after the event). Avoid sharing of refreshments at any point before or after events.
11. Lateral flow devices or PCR testing for performers are used in advance, where an audience is going to be present.
12. Avoid singing in areas with high disease prevalence.

It is also important to note that the advice for safer singing may reduce, but does not eliminate risk. Recently updated guidance for the performing arts in England also recommends steps are taken to discourage audiences from singing, shouting and chanting along [55,57], this is also consistent with advice in other countries.

Welsh Government guidance for the performing arts does already include advice for singers and musicians about the need for good ventilation and social distancing but not for audiences about singing and participation [56,58].

Research needs

The information on the factors that increase or decrease disease transmission during singing, vocalisation and music events remains very fragmentary. Considering the large numbers of people participating in multi-individual singing, worship, performing and musical activities in Wales this is an area where further research is urgently needed. The priorities for this include:

1. Experimental-based research needs to be undertaken to confirm aerosol and droplet generation rates across a wider range of scenarios (e.g. primary and secondary school vs. adult choirs, orchestras vs. small groups, tenors vs. sopranos) and in a range of spatial contexts (small poorly ventilated rooms vs. large ventilated halls).
2. Identify the best spatial conformation of singers and speakers to minimize transmission risk.
3. Use experimental data to better parameterise mathematical models which predict viral dispersal under an extensive range of different vocalisation scenarios.

4. Independently validate the mathematical simulations to provide confidence in the modelled outputs.
5. Undertake behavioural studies to better understand social interactions before, during and after performance events and compliance with guidelines. These should be contextualised by comparison with other events of a similar size (e.g. wet and dry hospitality).
6. Identify exemplars for communicating and implementing best practice for risk mitigation.
7. Critically evaluate the relative effectiveness of different non-pharmaceutical interventions (e.g. NPIs; air purifiers, face coverings, social distancing) at reducing the risk of disease transmission in different settings.
8. Undertake more epidemiological-based studies to evaluate transmission risk and attack rate during singing and performance events.

Conclusions

Communal singing, chanting and playing musical instruments is fundamental to the culture, health and wellbeing of the Welsh population. Based on this review, we conclude the following:

- There is very clear evidence that indoor communal singing (e.g. choirs) in the absence of any mitigation measures (NPIs) can result in the superspreading of COVID-19. Consequently, these events may pose high risk, particularly when high levels of COVID-19 are circulating in the population.
- There is no evidence that outdoor singing leads to disease superspreading. Consequently, these events pose low risk.
- The risk of viral aerosol generation, and thus disease transmission, appears to be significantly lower in children relative to adults.
- Most proposed mitigation measures to reduce disease transmission risk during communal singing or quiet chanting events are already commonplace in Wales (e.g. 2 m social distancing, use of face covering, hand hygiene, routine cleaning and disinfection of surfaces) giving confidence that events can occur safely (i.e. very low risk of disease transmission).
- The benefits of some mitigation options remain inconclusive or unproven (e.g. use of air purifiers, plastic shielding).
- Although definitive evidence is lacking, the risks of disease transmission from singing and performing are likely to be less or similar to hospitality, in that people gather from different households. Similar NPI mitigations are likely to be effective.
- When the incidence of SARS-CoV-2 circulating in Wales is low, then both indoor and outdoor singing-related activities should pose a very low risk, particularly if the mitigation strategies highlighted here are implemented.
- Guidance should be regularly reviewed in light of the potential for the emergence of vaccine-escaping or more transmissible variants of SARS-CoV-2.
- Further experimental and modelling based research is needed to better understand the dispersion of viral particles during different communal singing, chanting and performance scenarios. In addition, we need to undertake

fundamental research to better quantify the effectiveness of potential mitigation option. Lastly, behavioural studies are needed to better understand the barriers and opportunities to reduce transmission risk.

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