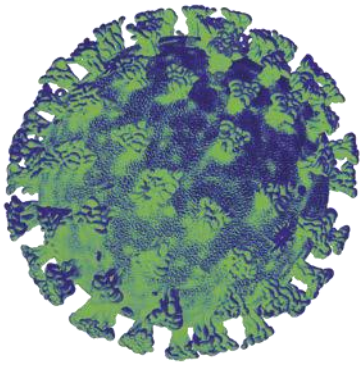
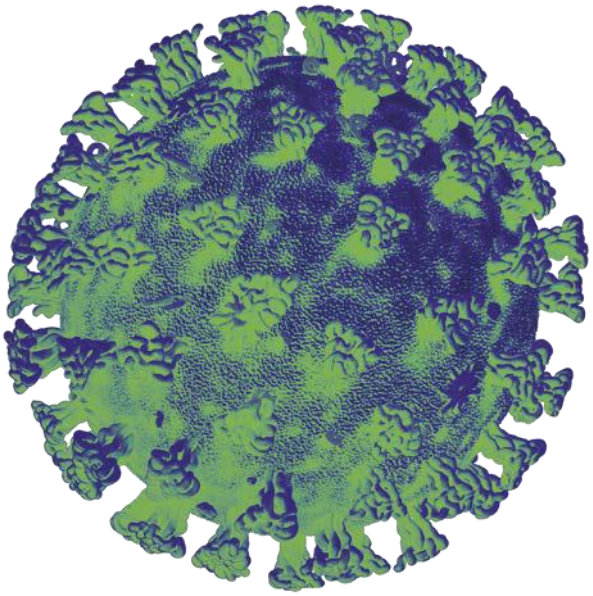
Llywodraeth Cymru
Welsh Government

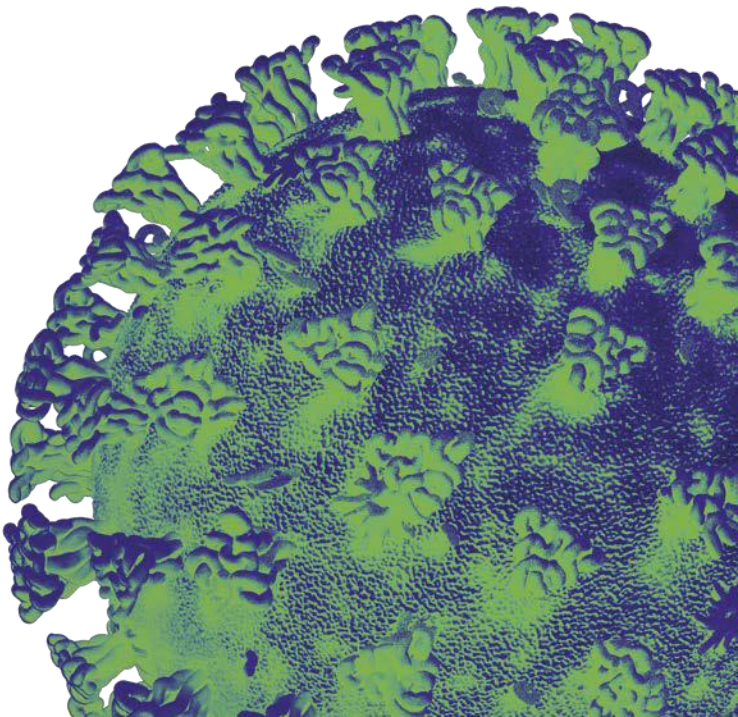
Technical Advisory Group

COVID-19 evidence associated with transmission and potential risks associated with religious activities and places of worship.

23 March 2021







COVID-19 evidence associated with transmission and potential risks associated with religious activities and places of worship.

Introduction

Wales is home to many different faiths/religions and denominations. It has been recognised that places of worship and religious activities in Wales are varied, all with differing practices and norms and take place in different environmental designs and settings. Whilst acknowledging there are other risks and harms such as wellbeing etc. to any restrictions etc. this paper serves to solely identify environmental risks in religious activities and the places of worship.

As ceremonies and practices of each religion differs, this document will not delve into the detail of each individual religion and denomination but will instead review generic risks applicable across practices. It should be noted that some places of worship operate commercial activities (e.g. coffee shops, renting out of facilities etc). Those activities are covered by advice and evidence relating to other sectors, and are not covered in this document.

Most transmission between individuals is likely to be underpinned by the generation of respiratory particles in the form of both droplets and aerosols which contain virus. Once droplets have been emitted by an individual, the virus they contain can be transmitted to others via a number of routes. This includes:

- Direct contact transmission[1,2]
    - Person to person
    - Droplet with direct deposition

- Indirect contact transmission [1,2]
    - Contaminated fomite (e.g. surfaces)
    - Aerosol

Individuals also shed virus up to 48 hours 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 can therefore take place while patients are pre-symptomatic [3,4]. There is also increasing evidence that a proportion of cases (estimates range between 20 and 70%) could be asymptomatic or pauci-symptomatic [5,6].

Activities that bring people together and by their nature involve increased respiratory particle generation are higher risk for enabling superspreading events. Additional environmental parameters (e.g. ventilation, temperature, humidity) may further enhance transmission in certain situations. Transmission of SARS-CoV-2 is strongly associated with proximity and duration of contact in indoor environments (high confidence) and the risk increases with duration of contact (SAGE-EMG, 2021). SARS-CoV-2 transmission is underpinned by superspreading events - in that a minority of cases are responsible for most transmission within the population.

Areas of potential risk

Risks are interconnected; super spreading is enabled by human behaviours combined with environmental factors. This means that any strategy to mitigate risk must look at how risks may interact and how mitigations are intended to function. This may be difficult to do in an experimental setting, and so may require careful consideration and interpretation of the evidence and biological characteristics of the pathogen. Ultimately the safest way to prevent transmission is to prevent mixing between individuals. Measures that are undertaken should therefore seek to minimise activities/contacts which increase the likelihood of an infected individual transmitting virus to non-infected individuals.

We identify two key areas of risk relating to environmental factors and human factors, which are evident from the literature in contributing to transmission risk, with these key risk areas having a number of elements that carry some form of risk;

1. From buildings
    - Ventilation, temperature and humidity
    - Surfaces
    - Social distancing/building layouts

2. From activities/human behaviour
    - Religious activities
    - Interactions between members of a community
    - Singing/chanting
    - Musical instruments

Each location/community is different so there must be an onus on local religious communities to undertake appropriate risk assessments and identify what is relevant to them in their practice. This list is also not exhaustive, and so additional activities and environmental risks may exist which are not summarised here. Local religious communities should be able to identify risks based on their own practices.

Current advice - Existing mitigations and evidence

Key to preventing infection is closing off potential routes for the virus to transmit between individuals. Many different activities - many of which may seem innocuous - can transmit the virus[10]. Early UK government advice focused on hand hygiene and physical and social distancing, with the addition of face coverings to advice as the scientific evidence base has developed to support this advice. These existing mitigations and advice are and remain highly relevant for places of worship and should form the starting point of mitigation measures for religious activities.

Specifically:

1. Hand hygiene is recommended due to the potential for viral survival on surfaces, which has been estimated to be hours to days, depending on the environment and material[1,11,12]. The survival of SARS-CoV-2 on surfaces also underpins advice around cleaning. Specific risk advice should be used for faith based activities such as administration of communion, washing ceremonies after death, or other ceremonies that may involve direct contact.

2. Physical distancing focuses on reducing the probability of a 'contact' with an infected person resulting in a transmission. There is a wide body of evidence that points to social distancing of 2 m as producing a reduction in the probability of transmission [13]. It is important to note that droplet spread depends on the violence of the respiratory event. Coughing and sneezing will spread droplets explosively - but droplets can also be generated and be spread when speaking. Increasing volume (of talking/speaking/singing) evidence points towards increased droplet generation[14], an observation that is of particular relevance to religious practice. The effectiveness of physical distancing is likely to be highly dependent upon environmental factors.

3. Face coverings and face masks. Wearing masks is principally to reduce risks to others, rather than to protect oneself. Secondly, as the principal routes of infection is via droplets that are inhaled or from transfer of virus from environmental surfaces to an individual's mouth or eyes, masks provide a physical barrier that may reduce transmission. Evidence points towards the fact that both face masks and face coverings can reduce transmission of COVID-19 [13].
4. Effective cleaning of high contact touch points will help reduce the risk of direct transmission.

5. Promote advice that anyone with symptoms avoids communal attendance, seeks testing and engages with appropriate household isolation and contact tracing

In relation to the new B.1.1.7 Kent variant, previously identified personal, procedural, engineering and societal mitigations to reduce transmission of SARS-CoV-2 virus all continue to apply to the new variant, but are likely to require a step change in rigour of application given that the new variant is likely to represent a significantly increased transmission risk (high confidence).

Areas of potential risk - Buildings

Whilst not exclusive, most acts of worship take place indoors inside a place of worship. The transmission risks of SARS-CoV-2 are considerably higher indoors compared to outdoors (18.7 × higher, 95% confidence interval: 6.0-5.7.9; Bulfone et al. 2020).

Ventilation, temperature and humidity

Environmental conditions affect the spread, size and settling of respiratory particles. This is an area that has been studied particularly in Influenza, and is particularly relevant to places of worship.

Specifically, there is evidence relating to viral transmission being affected by:

- Ventilation (identified as being important to reduce transmission in a number of environments [7-8])
- Temperature (identified as contributing to transmission potential and environmental survival [9–11])
- Humidity (droplet dispersal, environment survival and transmission [12–14,15])

These observations are all directly relevant to places of worship. In addition, the layout of places of worship, and the condition of buildings may also be relevant - as features such as poor heating or low relative humidity within the buildings could create a situation similar to that observed in other environments such as meat processing plants which may serve to improve the dispersion and transmissibility of the virus.

Surfaces

The contamination of surfaces and surface survival of SARS-CoV-2 [16] [17] is relevant particularly in the case of places of worship. Cleaning and decontamination is critical to ensure that virus does not survive on surfaces. In the case of places of worship that are open a small number of times per week, it may be advisable to use knowledge of the survival of SARS-CoV-2 to plan cleaning to reduce the risk to staff/volunteers from surfaces contaminated with SARS-CoV-2. Effective mitigations would include plans to

avoid shared surfaces (such as books or sheets) by means such as use of own or projected electronic media for orders of service etc.

Design of the building

Specific information relating to the design of places of worship is not available with respect to the impact that this may have on transmission. Places of worship can vary significantly in design, and this design may affect the temperature, humidity and circulation/mixing in the place of worship. The design may also impact the potential for social distancing (e.g. the use of fixed vs movable seating), and may also affect turbulence/mixing in the air (high vs low ceilings). Some places of worship may have ineffective heating, or they may make use of recirculation which is not filtered. Building design will affect the ability to maintain a one way system for entry and exit.

Areas of potential risk - Activities

Acts of worship, activities and practices

There are a general set of activities associated with religious practice that may pose a risk to worshippers. Religious practice involving water (e.g. washing of hands in communal vessels) or the sharing of food, drink (e.g. drinking from a shared cup) and other items (such as books, collections, religious symbols, seating) carry immediate and obvious risks as they provide a direct route for infection between individuals [57,58].

As part of religious ceremonies and acts of worship, people may mix more closely and there is the potential that there is a lack/lapse in social distancing - which has been implicated as a key factor in a number of outbreaks (identified as a factor in [18,19,20,59,60,61]). For most religions, religious practice is based around a sense of community, with worshippers having friendship networks within the religious grouping where they are located. Behaviour such as greeting each other at the door or close contact (hugs, shaking hands) are, in normal times, usual practice. In all of these cases, these behaviours pose a higher risk for transmission. In addition, many faiths and belief groups lead to greater social cohesion which may indirectly facilitate closer social contact and thus risk of transmission [61].

There are also risks associated with activities surrounding acts of worship or ceremonies such as visiting the toilets (https://gov.wales/technical-advisory-group-sars-cov-2-transmission-risk-public-toilets), travel to and from the venue/area (sharing cars, public transport), and congregating outside the venue.

Lastly, many religious ceremonies or practices are multi-generational, and places of worship are likely to bring together a wide range of age groups. This intergenerational mixing provides a potential route for infection and secondary attacks which may not be present through most other activities that would normally be undertaken outside of a family grouping.

Evidence for risks related to COVID-19 in relation to singing

SARS-CoV-2 is increasingly being shown to spread predominantly by so-called 'superspreading events' [21,22]. This is consistent with the behaviour of other coronaviruses [23,24], 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. 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 [25]. Over the course of the SARS-CoV-2 pandemic so far, superspreading events have been linked to a variety of environments or events – from weddings to workplaces.

In one such database of reported superspreading events [26], 239 of 1665 the entries mark the event as being related to 'vocalisation' encompassing an estimated 49,000 cases. Of these, 15 events were associated with Choir practices or recitals, two were associated with concerts and an additional 31 were associated with other religious activities. This would suggest that singing and other forms of vocalisation louder than talking may carry an increased risk, however, this data is not systematically collected and the environmental factors that enhance viral transmission are multifaceted. 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. Moreover, by their nature analyses and investigations of superspreading events are retrospective.

Singing

A study of influenza suggests that vocalization might be critical for creation of infection breath particles (J. Ma et al.,2020). Whilst increased vocalisation increases the spread and speed of viral particles. 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 [27,28] and live events [18,19,20]. However these data do not include the very large exposure to such events for comparison, and most predate the use of precautions such as social distancing and avoiding shared surfaces. 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 [29,30].

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 greatly in size and thus travel different distances [31,32]
- Activities involving speaking, singing or exhaling breath forcibly result in greater aerosol or droplet generation [33,34]
- The louder/more sustained the activity, the more aerosol or droplets are generated [33,35]
- The amount of virus emitted by an individual varies, depending on a number of factors. [36,35]
- Some individuals can be super-emitters [36]

In essence, there is strong evidence that vocalisation (speaking, singing or chanting) 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.

Other related factors that have been identified as affecting risk of transmission include;

- Duration of performance (longer duration equals higher risk)[37]
- Number of singers (more singers potentially equates to higher risk) [37]
- Audience behaviour (e.g. singing along by the audience)[37]
- 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 [38])
- Use of masks/visors/physical barriers (may reduce spread although while there is evidence around masks and visors [38,39,40], 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 [40].

In relation to singing of hymns, other religious songs, and prayers etc., all of which form part of religious ceremonies and activities, the evidence suggests there is increased risk of transmission.

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 [30,41]. 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[30]. 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. This evidence suggests that mitigation measures may need to vary based upon the instrument(s) being utilised [42].

Other risks relevant to religious activity

Age structure / age risk

In October 2020, data although caveated and based on Welsh Government analysis of Annual Population Survey datasets provided by the Office for National Statistics in Table 1 showed 47.9% were Christian, 1.8% identified as Muslim, and 2.7% identified as having 'other' religions. 29.6% of those in the Christian faith were over 65%, 24.2% from other religions were over 65 whilst no data was present for those over 65 in the Muslim faith.

Age		Religion: Total: No Religion	Christian	Muslim	Any Other Religion	Total: Total
Total		1,469,000	1,486,500	(!) 55,500	84,400	3,102,900
Total	Age 0-15	331,400	202,600	(!!) 18,400	(!!) 8,400	562,000
	Age 16-24	208,700	118,800	(!!) 9,300	(!!) 6,200	345,200
	Age 25-44	450,900	249,400	(!!) 17,900	(!) 22,300	742,600
	Age 45-64	345,200	440,200	(!!) 8,300	(!) 27,000	822,000
	Age 65+	132,800	475,500	*	(!) 20,500	631,300

Table 1: https://statswales.gov.wales/Catalogue/Equality-and-Diversity/Religion/religion-by-age

Relevant evidence from other pathogens

As has been evidenced by a number of outbreaks this year, certain environmental factors (low temperature, low humidity, noisy environments) appear to make transmission more likely [26,43,44].

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 [15,38,45], 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 number of significant TB outbreaks have been linked to singing [46,47,48], 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. [48,49-50,51]).

References

1. Lake, M. A. What we know so far: COVID-19 current clinical knowledge and research. *Clin. Med.* **20**, 124–127 (2020).
2. Kutter, J. S., Spronken, M. I., Fraaij, P. L., Fouchier, R. A. M. & Herfst, S. Transmission routes of respiratory viruses among humans. *Current Opinion in Virology* vol. 28 142–151 (2018).
3. He, X. *et al.* Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat. Med.* **26**, 672–675 (2020).
4. Goldberg, S. A. *et al.* Presymptomatic Transmission of SARS-CoV-2 Amongst Residents and Staff at a Skilled Nursing Facility: Results of Real-Time PCR and Serologic Testing. *Clinical Infectious Diseases* (2020) doi:10.1093/cid/ciaa991.
5. He, W., Yi, G. Y. & Zhu, Y. Estimation of the basic reproduction number, average incubation time, asymptomatic infection rate, and case fatality rate for COVID- 19: Meta-analysis and sensitivity analysis. *Journal of Medical Virology* (2020) doi:10.1002/jmv.26041.
6. Kronbichler, A. *et al.* Asymptomatic patients as a source of COVID-19 infections: A systematic review and meta-analysis. *Int. J. Infect. Dis.* (2020)

doi:10.1016/j.ijid.2020.06.052.

7. Nissen, K. *et al.* Long-distance airborne dispersal of SARS-CoV-2 in COVID-19 wards. *Sci. Rep.* **10**, 19589 (2020).
8. Somsen, G. A., van Rijn, C., Kooij, S., Bem, R. A. & Bonn, D. Small droplet aerosols in poorly ventilated spaces and SARS-CoV-2 transmission. *Lancet Respir Med* **8**, 658–659 (2020).
9. Lai, M. Y. Y., Cheng, P. K. C. & Lim, W. W. L. Survival of Severe Acute Respiratory Syndrome Coronavirus. *Clin. Infect. Dis.* **41**, e67–e71 (2005).
10. Dietz, L. *et al.* 2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations To Reduce Transmission. *mSystems* **5**, (2020).
11. Mecenas, P., Bastos, R. T. da R. M., Vallinoto, A. C. R. & Normando, D. Effects of temperature and humidity on the spread of COVID-19: A systematic review. *PLoS One* **15**, e0238339 (2020).
12. Ward, M. P., Xiao, S. & Zhang, Z. Humidity is a consistent climatic factor contributing to SARS- CoV- 2 transmission. *Transboundary and Emerging Diseases* (2020) doi:10.1111/tbed.13766.
13. Ravelli, E. & Martinez, R. G. Environmental risk factors of airborne viral transmission: Humidity, Influenza and SARS-CoV-2 in the Netherlands. doi:10.1101/2020.08.18.20177444.
14. Raines, K. S., Doniach, S. & Bhanot, G. The transmission of SARS-CoV-2 is likely comodulated by temperature and by relative humidity. doi:10.1101/2020.05.23.20111278.
15. Lowen, A. C., Mubareka, S., Steel, J. & Palese, P. Influenza virus transmission is dependent on relative humidity and temperature. *PLoS Pathog.* **3**, 1470–1476 (2007).
16. Kampf, G., Todt, D., Pfaender, S. & Steinmann, E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J. Hosp. Infect.* **104**, 246–251 (2020).

17. Van Doremalen, N. *et al.* Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N. Engl. J. Med.* **382**, 1564–1567 (2020).
18. Streeck, H. *et al.* Infection fatality rate of SARS-CoV-2 infection in a German community with a super-spreading event. doi:10.1101/2020.05.04.20090076.
19. Koizumi, N., Siddique, A. B. & Andalibi, A. Assessment of SARS-CoV-2 transmission among attendees of live concert events in Japan using contact-tracing data. *J. Travel Med.* **27**, (2020).
20. Sugano, N., Ando, W. & Fukushima, W. Cluster of Severe Acute Respiratory Syndrome Coronavirus 2 Infections Linked to Music Clubs in Osaka, Japan. *J. Infect. Dis.* **222**, 1635–1640 (2020).
21. Adam, D. C. *et al.* Clustering and superspreading potential of SARS-CoV-2 infections in Hong Kong. *Nature Medicine* vol. 26 1714–1719 (2020).
22. Liu, Y., Eggo, R. M. & Kucharski, A. J. Secondary attack rate and superspreading events for SARS-CoV-2. *Lancet* **395**, e47 (2020).
23. Kucharski, A. J. & Althaus, C. L. The role of superspreading in Middle East respiratory syndrome coronavirus (MERS-CoV) transmission. *Euro Surveill.* **20**, 14–18 (2015).
24. Shen, Z. *et al.* Superspreading SARS events, Beijing, 2003. *Emerg. Infect. Dis.* **10**, 256–260 (2004).
25. Frieden, T. R. & Lee, C. T. Identifying and Interrupting Superspreading Events—Implications for Control of Severe Acute Respiratory Syndrome Coronavirus 2. *Emerging Infectious Diseases* vol. 26 1059–1066 (2020).
26. Koen. Database. https://covid19settings.blogspot.com/p/blog-page.html (2020).
27. Charlotte, N. High Rate of SARS-CoV-2 Transmission due to Choir Practice in France at the Beginning of the COVID-19 Pandemic. doi:10.1101/2020.07.19.20145326.
28. Hamner, L. *et al.* High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020. *MMWR. Morbidity and Mortality Weekly Report*

vol. 69 606–610 (2020).

29. Bahl, P. *et al.* Droplets and Aerosols generated by singing and the risk of COVID-19 for choirs. *Clin. Infect. Dis.* (2020) doi:10.1093/cid/ciaa1241.
30. Echternach, M. *et al.* Impulse Dispersion of Aerosols During Singing and Speaking: A Potential COVID-19 Transmission Pathway. *Am. J. Respir. Crit. Care Med.* (2020) doi:10.1164/rccm.202009-3438LE.
31. Fennelly, K. P. Particle sizes of infectious aerosols: implications for infection control. *Lancet Respir Med* **8**, 914–924 (2020).
32. Asadi, S., Bouvier, N., Wexler, A. S. & Ristenpart, W. D. The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? *Aerosol Sci. Technol.* **0**, 1–4 (2020).
33. Morawska, L. *et al.* Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *Journal of Aerosol Science* vol. 40 256–269 (2009).
34. Reid, J. Comparing the Respirable Aerosol Concentrations and Particle Size Distributions Generated by Singing, Speaking and Breathing. doi:10.26434/chemrxiv.12789221.v1.
35. Nicas, M., Nazaroff, W. W. & Hubbard, A. Toward Understanding the Risk of Secondary Airborne Infection: Emission of Respirable Pathogens. *Journal of Occupational and Environmental Hygiene* vol. 2 143–154 (2005).
36. Asadi, S. *et al.* Aerosol emission and superemission during human speech increase with voice loudness. *Sci. Rep.* **9**, 2348 (2019).
37. Naunheim, M. R. *et al.* Safer Singing During the SARS-CoV-2 Pandemic: What We Know and What We Don't. *Journal of Voice* (2020) doi:10.1016/j.jvoice.2020.06.028.
38. What is the evidence to support the 2-metre social distancing rule to reduce COVID-19 transmission? - CEBM. *CEBM* https://www.cebm.net/covid-19/what-is-the-evidence-to-support-the-2-metre-social-distancing-rule-to-reduce-covid-19-transmission/.

39. Chu, D. K. *et al.* Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *Lancet* **395**, 1973–1987 (2020).

40. CDC. Considerations for Wearing Masks. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html (2020).

41. [No title]. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/914628/S0695_Aerosol_and_Droplet_Generation_from_Singing__Wind_Instruments__SWI__and_Performance_Activities.pdf.

42. He, R., Gao, L., Trifonov, M. & Hong, J. Aerosol generation from different wind instruments. *J. Aerosol Sci.* **151**, 105669 (2021).

43. Taylor, C. A., Boulos, C. & Almond, D. Livestock plants and COVID-19 transmission. *Proc. Natl. Acad. Sci. U. S. A.* (2020) doi:10.1073/pnas.2010115117.

44. Middleton, J., Reintjes, R. & Lopes, H. Meat plants—a new front line in the covid-19 pandemic. *BMJ* m2716 (2020) doi:10.1136/bmj.m2716.

45. Lowen, A. C. & Steel, J. Roles of humidity and temperature in shaping influenza seasonality. *J. Virol.* **88**, 7692–7695 (2014).

46. Sacks, J. J., Brenner, E. R., Breeden, D. C., Anders, H. M. & Parker, R. L. Epidemiology of a tuberculosis outbreak in a South Carolina junior high school. *American Journal of Public Health* vol. 75 361–365 (1985).

47. Washko, R., Robinson, E., Fehrs, L. J. & Frieden, T. R. Tuberculosis Transmission in a High School Choir. *Journal of School Health* vol. 68 256–259 (1998).

48. Ridzon, R. *et al.* Outbreak of drug-resistant tuberculosis with second-generation transmission in a high school in California. *The Journal of Pediatrics* vol. 131 863–868 (1997).

49. Du, C.-R. *et al.* Effect of ventilation improvement during a tuberculosis outbreak in

underventilated university buildings. *Indoor Air* **30**, 422–432 (2020).

50. Escombe, A. R. *et al.* Improving natural ventilation in hospital waiting and consulting rooms to reduce nosocomial tuberculosis transmission risk in a low resource setting. *BMC Infectious Diseases* vol. 19 (2019).

51. Escombe, A. R. *et al.* Natural ventilation for the prevention of airborne contagion. *PLoS Med.* **4**, e68 (2007).

52. Ahmed, N. *et al.* Faith, planning and changing multiculturalism: constructing religious buildings in London's suburbia. *Ethnic and Racial Studies* **43**, 1542-1562 (2020).

53. National Churches Trust. The House of Good: The economic and social value of church buildings to the UK. National Churches Trust, London, UK. pp. 35 (2020).

54. DeSouza *et al*. Coping with racism: A perspective of COVID-19 church closures on the mental health of African Americans. *Journal of Racial and Ethnic Health Disparities in* press (2020).

55. Payne, R. *et al.* Social enterprise and rural places of worship in England. Plunkett Foundation, Woodstock, Oxon, UK (2017).

56. Parish Resources. Coronavirus (COVID-19) financial guidance for churches. Archbishops' Council, London (2020).

57. Spantideas, N. *et al.* COVID-19 and Holy Communion. *Public Health* **187**, 134-135 (2020).

58. Pellerin, J., and Edmond, M.B. Infections associated with religious rituals. *International Journal of Infectious Diseases* **17**, e945-948 (2013).

59. Gerbaud, L. Hospital and Population-Based Evidence for COVID-19 Early Circulation in the East of France. *International Journal of Environmental Research and Public Health* **17**,

7175 (2020).

60. Saidan, M.N. Estimation of the probable outbreak size of novel coronavirus (COVID-19) in social gathering events and industrial activities. *International Journal of Infectious Diseases* **98**, 321-327 (2020).

61. Vermeer, P. Religion and the Transmission of COVID-19 in The Netherlands. *Religions* **11**, 393 (2020).