16th March 2021

Science framework for opening up group events

This paper is a response to a DCMS Commission (Appendix A) to inform a research programme to be overseen by the DCMS Science Board (Appendix C) focusing on opening events and venues with minimal transmission risk. It was prepared by a Working Group organised by SAGE-EMG and DCMS that included participants in several SAGE subgroups (EMG, SPI-B, SPI-M) and others (Appendix B).

Summary

I Priority research questions

One primary and one secondary scientific question were identified as priorities to be addressed in the first three months of an events research programme to inform opening up events and venues:

i. Given a pre-specified set of mitigation measures, is there evidence of an increased risk of transmission of SARS-CoV-2 from attendance at (a) outdoor and (b) indoor events?

ii. Which characteristics of events and venues and behaviours likely contribute most to transmission?

There is likely to be a balance between internal validity and generalisability. A large-scale randomised trial at a single event is likely to provide the highest quality evidence of any potential increased risk. However, the results may not be generalisable to other settings (e.g. smaller indoor venues). Analysing data across multiple smaller pilots could improve generalisability potentially allowing comparison of risk across settings. However, very large aggregate attendee and control sample sizes are likely to be necessary to estimate epidemiologically meaningful differences in risk across event types as differences in absolute risk are likely to be small and clustering of cases (for reasons unrelated to the events) is likely to reduce statistical power.

II Principles for design and evaluation of pilots

i. Design: a range of studies and study designs is needed to optimise causal inference ranging from randomisation for large scale events to meta-analyses of case control and cohort studies for smaller events designed to allow comparison.
ii. Measures: core set of measures across studies - biological; environmental; behavioural
iii. Ethical: generate high quality evidence, transparently, treating everyone with equal moral value, with minimal suffering
iv. Open science: use the practices of open science including pre-registration of protocols

III Best practice approaches for an events research programme

i. The research programme should aim to generate the highest quality evidence based on the principles outlined above to enable performing arts, live music and sporting events to resume sustainably with minimal risk of transmission.

ii. Results from the research programme will need to be pooled across studies to have the statistical power to address the priority questions, requiring the same or similar designs and measures for similar types of events and venues.

iii. Studies should be informed by existing theory and evidence regarding behaviour in crowds at events, its measurement and interventions to change it.

iv. Establish a living review of evidence focusing on the primary and secondary questions above, and building on the rapid review underway by PHE

I Priority questions

One primary and one secondary scientific questions were identified as priorities to be addressed in the first few months - of an events research programme to inform opening up events and venues with maximum capacity and minimal transmission of the virus:

i. Given a pre-specified set of mitigation measures, is there evidence of an increased risk of transmission of SARS-CoV-2 from attendance at (a) outdoor and (b) indoor events?

ii. Which characteristics of events, behaviours and venues likely contribute most to transmission?

It should be stressed that it is generally not possible to estimate an increase in risk from attendance of an event compared with controls who have similar characteristics and did not attend the event. Instead, it is possible - statistically - to rule out a given increase in risk (i.e. any increase in risk is likely to be smaller than x). The larger the study, the smaller the potential increase in risk that can be ruled out. This is true for a single large event, or for aggregating across smaller events.

Results from this initial phase, together with other emerging evidence, should be used to inform a second phase which may include evaluation of the effectiveness of different mitigation measures, as well as observational studies including those investigating displaced risks (*eg* behaviour of those unable to attend events) and unintended consequences (perhaps due to opening some events and not others). It should be stressed that caution needs to be applied when analysing observational data aggregated over multiple studies, as risks are likely to be low and cases are likely to cluster in space and time for reasons unrelated to the event(s). In addition, studies of small events are unlikely to be powered to test non-inferiority per event. Hence, it is likely that - for small events - not enough evidence will be obtained to make decisions at the event level.

Pre-specified mitigation measures

These would need to be agreed between DCMS, PHE and others in accordance with existing guidelines (Appendix E). They will include: layout of the venue; reduced capacity attendance; testing requirements for participants *eg* receipt of a negative test result from a rapid test shortly before entry to an event; a testing regimen for staff and others at an event*; wearing of face coverings.
**those running events as part of the pilots are expected to agree to pay full salaries and provide other support as needed for staff and performers required to self-isolate.*

Characteristics of events and venues that may affect transmission

Below is a non-exhaustive list of measures needed to characterise events and venues as a basis for understanding transmission to be refined by existing and emerging evidence.

1. Number attending (including staff)
2. Demographic profiles of those attending (including age, ethnicity, index of deprivation, occupation and vaccination status)
5. Audience behaviour: active to passive
5. Most risky aspects
- *a. Physical characteristics of facilities including:*
  - *i. Indoor or outdoor*
  - *ii Ventilation [See note on measurement in Appendix G]*
  - *iii. Seated vs unseated*
  - *iv. Lavatories*

v. *Entrances/exits*
vi. *Flow of people*
vii. *Physical space separation*
viii. *Volume and area per person*

b. *Duration of event and intervals between events*
c. *Number and duration of intervals*
d. *Sharing food and drink*
e. *Alcohol*
f. *Face coverings: use and type*
g. *Availability of hand sanitiser*
h. *Frequency and extent of cleaning of surface touch-points during event*
i. *Pre/Post event activities :travel, socialising and engagement with testing*
j. *Time of event (evening vs daytime)*

II Principles for design and evaluation of pilots

i. Epidemiological design considerations

There is a need to generate high quality data to estimate the level of risk associated with attendance of different types of events in venues with different characteristics and mitigation measures in place (see above). This implies measuring rates of confirmed SARS-CoV-2 infection in attendees and ideally comparing these rates with similar individuals that did not attend the event.

A range of studies should be undertaken, including descriptive studies allowing comparison across groups, analytical studies (e.g. case control or cohort studies) and experimental studies (trials). A well conducted randomised controlled trial provides the best quality evidence to assess any causal association between attendance of events and the risk of acquiring SARS-CoV-2 and should ideally be undertaken in at least one setting. Other experimental or quasi-experimental designs include a stepped wedge cluster trial (in which roll-out of opening would be done in a random order) and A-B-A reversal designs (with venue systematically varied) which could be used to assess the impact of mitigation measures.

Although a range of studies should be conducted, wherever possible they should all use similar definitions (e.g. case definitions) and laboratory methods as well as similar data architectures so that the individual-level data can be easily combined to potentially increase power (whilst taking account different settings and populations).

Ideally these studies should be conducted in a clearly defined, well enumerated population using consistent laboratory and case definitions, so that background levels of COVID-19 confirmed disease can be estimated.

In addition, these studies should include events at outdoor and indoor venues, as well as those that are seated and unseated.

Prevalence: The prevalence of COVID-19 at the time that these studies are undertaken will be a major determinant of the study design and the outcomes that can be measured. In late February 2021 the ONS Community Infection Survey suggested that the prevalence of COVID-19 was about 1 in 200. It is very difficult to predict the incidence in late April when these pilots are likely to take place as various restrictions will be lifted by then, and the school Easter break will intervene.

Nevertheless, assuming that prevalence is roughly similar at the time of the studies as it was in late February and that all participants would be screened with a lateral flow test (with 75% sensitivity) before entry then the prevalence of infected individuals gaining entrance to a venue would be around 1 in 800. Single events that are smaller than this are therefore unlikely to have an infectious individual attending. Smaller events can be used to test systems and assess the uptake and acceptability of mitigation measures. Data from across multiple smaller events can also be combined to increase power. However, it is likely that much larger studies will be necessary to assess any epidemiological impact or indeed to detect virus through environmental sampling. Appendix F gives example sample size calculations for a potential randomised controlled trial in an outside venue. It is clear that any randomised trial will need tens of thousands of participants and controls (who do not attend the event) as the prevalence will be low and the risk associated with attendance is likely to be small. A meta-analysis of similar smaller studies is likely to require higher overall sample sizes as clustering of cases in space and time (unrelated to the events) will reduce statistical power.

Low prevalence in attendees at events also means that post-event testing should use highly specific and sensitive tests (ideally PCR). The use of lateral-flow devices (LFDs) to test for infection after an event without PCR confirmation should be avoided as the lower specificity of LFDs will result in a high fraction of false positives. This would seriously affect the interpretability of the results of the study. Importantly, a high fraction of false positives could bias results towards the null, *i.e.* lead to underestimation of risk of event attendance.

Given these considerations, pooling results across studies will provide an estimate of the increase in transmission of SARS-CoV-2 that can be ruled out from attendance at events. They will not provide an estimate of the risk of transmission of SARS-CoV-2 from attendance. Furthermore, any such pooled analyses will have to be very carefully conducted to ensure that appropriate inferences are drawn (see section on Smaller venues or events).

Unit of study: could be attendees or venues (e.g. a cluster randomised study). Choosing venue as the unit of study would be used to assess the role of venue-specific mitigation measures. Cluster randomised trials are less efficient than individual-randomised trials and so if SARS-CoV-2 infection in participants is the outcome, then – other things being equal – such a study would need to be larger than an individual-randomised trial in terms of total number of individuals participating.

Outcomes: For epidemiological studies, outcomes should be SARS-CoV-2 infection in a defined period (see later) following attendance at an event.

Study population: Outcomes can be measured in either staff, attendees or both. Indeed, as staff are exposed on a more regular basis than attendees (i.e. daily versus occasionally) they should be included in any study. Outcomes in staff should be analysed separately from outcomes in attendees because of the differential exposure and difficulty determining a control group.

Investigation of cases: genetic sequencing of positive cases and/or spatial clustering for seated events can be used to further assess the likelihood of transmission at the event in question for any cases that are identified afterwards.

Large venues or events (tens of thousands of attendees)

Prevalence could be high enough to measure a difference in risk by attendance or not. Experimental or analytical epidemiological studies with SARS-CoV-2 as an outcome may be feasible, though even then data may have to be combined across multiple events to generate sufficient power to detect or rule out a given increase in risk.

An outline of a proposed trial for a large outdoor event is given in Appendix F.

Smaller venues or events

Any single smaller event is likely to admit no infected individuals, given low population prevalence, the size of the events and pre-testing. Hence, to study risk of SARS-CoV-2 infection, data will have to be combined across multiple events (perhaps multiple venues over many days). Even if appropriate control groups (who did not attend the event) are identified and followed up, caution will be required in interpreting results from smaller studies as prevalence is likely to be low and cases are likely to cluster in space and time for reasons unrelated to the event. Large sample sizes (large aggregate numbers of participants and controls) are therefore likely to be necessary. This will be even more apparent if the aim is to compare the risks across different settings and/or different mitigation measures. Here, the combination of low prevalence, existing mitigation measures and background clustering of cases in space and time, means that very large aggregate sample sizes are likely to be necessary to be able to draw any firm conclusions about possible changes in risk by setting or mitigation measures.

It may be operationally difficult to conduct a randomised trial over multiple venues and multiple occasions, and so observational or analytical studies (e.g. cohort studies) may be required. Causal inferences related to risk by type of venue and mitigation measures are likely to be very challenging under these circumstances.

Ideally, controls who did not attend the event/events should also be followed. Care will be required to appropriately take account of confounders and potential biases. For instance, those who attend events may have higher rates of exposure unrelated to the event or events in question. The use of "population controls" (i.e. the background rate of SARS-CoV-2 infection) should ideally be avoided for this reason.

Ideally, attendees would be followed up actively with a PCR test post-event. Incentivising participants and controls (where appropriate) to participate in post-event testing will be critical. Incentives might include offering reduced ticket prices for future events, or ensuring that participants and controls are prioritised for future tickets.

In addition, or as an alternative, the rates of infection in staff (public vs non-public facing) should be compared. Indeed, in smaller venues, closely following swab positivity in staff over an extended period of time may be the only feasible way to estimate any increase in risk (comparing SARS-CoV-2 infection rates between customer-facing and non-customer-facing staff).

Conducting multiple smaller events within the same geographic region may provide information on the aggregate effects of these events to a local population. As with all ecological analyses, care would need to be taken to avoid drawing inappropriate inferential conclusions as there are likely to be multiple other factors that are changing over time by geographical location, and observed changes in prevalence at the aggregate level may not be causally related to patterns of individuals' attendance of events.

Selection of events and venues

Events and venues should be selected to reflect demographic and geographical diversity to maximise generalisability of findings in accord with ethical considerations for research in an emergency (*p 9*).

ii. Measures

Details of these measures and considerations for their use are provided in Appendix G

Biological

Testing to identify infectious individuals pre-event

i. Two lateral flow tests, one within 24h the other within 5 days of indoor event
ii. One lateral flow test within 24h of an outdoor event, conducted at asymptomatic testing centres

Testing to identify infected individuals linked to transmission at the event

iii. Quantitative PCR 5-7 days after the event – this could be by a home test supplied on exiting venue and date stamped with a text reminder on the test day – return rate may be poor without incentive – alternatively supply PCR to asymptomatic testing centres
iv. Beyond 7-10 days transmission may be after the event – trade-off between detecting slow incubators and minimising inclusion of post-event transmissions

Environmental

Sampling for SARS-CoV-2 RNA screening

Given very low numbers of infected people at any event, any environmental sampling should use methods with the lowest detection limits *i.e.* high volume sampling, wide area surface sampling, concentrated waste water samples, all assessed against pre-event levels.

Wastewater sampling considered for larger events given access to a waste water sewer.

Surfaces swabs of commonly touched surfaces *eg* door handles, toilet areas, hand sanitiser dispensers

Air could be sampled using specialist high volume samplers *eg* at pinch points such as entrances or exits and around activities associated with transmission *eg* singing, shouting.

Ventilation

Ventilation characteristics of venues for different events should be recorded to reduce the uncertainty around thresholds for risk of transmission starting with measures listed in Appendix G.

Behavioural measures

Based on observation, not self-report:

Physical distancing: quantified using images from cameras placed around and inside venues
Forms of greeting: (handshakes, fistbumps, hugs, other) quantified in the same way
Physical distance x time: measured between participants and staff using wearable devices
Wearing face-coverings: proportion wearing and wearing correctly, using images from cameras
Hand hygiene: measured by volume of hand-sanitiser and soap dispensed at venues

Singing, chanting, shouting quantified using both filmed images and volume of sound
Sharing food and drink quantified using filmed images.

Surveys and qualitative studies can provide additional measures of process (Appendix G).

iii. Ethical considerations for research

These draw upon Nuffield Council on Bioethics report on research in global emergencies[1,2]

The ethical importance of learning: Policy decisions about events are important opportunities to generate evidence for the current pandemic and also for future infectious disease outbreaks. It would be unethical to fail to ensure learning from these decisions through rigorous well-designed research and evaluation and structured piloting of policy options. This should include social science and ethics components to ensure that such learning is contextual, qualitative, and capable of identifying and analysing ethical considerations.

Transparency and inclusiveness of decision-making: Decisions about allowing events raise important questions arising out of the tensions between different values, priorities, and commitments, and may be controversial. Transparency and inclusiveness in decision-making are essential for public trust and confidence. An active Patient and Public Involvement and Engagement (PPIE) panel will be important in this regard.

Consent and community engagement: Running pilot events will have implications for those who attend as participants and as employees. They will also increase the risk of infection, even if modestly, for those who subsequently come into contact with those who attend. It is vital that such decisions are made in ways that are inclusive, co-produced, and that clear, accessible justifications are provided. This will include careful consideration of risks and benefits including the likelihood of false negative pre-event test results and the consequent risks to those who attend. Careful attention should be paid to ensuring that risks are minimised. Decisions to undertake pilots – and about the size and location of such gatherings - should be informed by evidence about the extent to which the pandemic is under control: successful vaccine rollout, vaccine efficacy, the potential for escape variants, and pressure on the NHS.

Equal moral value: It is vital both for public trust and for equity that there is fair selection of events for piloting. People will place special value on events of different kinds - large weddings, funerals, religious gatherings, sports events, and the arts will each be seen as priorities by many. In all decisions particular attention should be paid to the impact on, and prioritise the interests of, those who are worst off.

Independent ethical review: Pilot studies should be subject to independent ethical scrutiny. Those running them should have access to ethics support and advice to enable the timely identification and addressing of emerging ethical concerns.

Research governance

We recommend that ethics approval is sought at national level, possible from the Health Research Authority https://www.hra.nhs.uk/

Open Science

In keeping with the principles of open science[3,4], research protocols should be pre-registered on ISRCTN, OSF or similar platforms.

1. *Nuffield Council on Bioethics. Research in global health emergencies: ethical issues. London: Nuffield Council on Bioethics; 2020.*
2. *Wright KS. Ethical research in global health emergencies: making the case for a broader understanding of 'research ethics'. International Health. 2020 Nov;12(6):515-7.*
3. *Munafò MR, Nosek BA, Bishop DV, Button KS, Chambers CD, Du Sert NP, Simonsohn U, Wagenmakers EJ, Ware JJ, Ioannidis JP. A manifesto for reproducible science. Nature human behaviour. 2017 Jan 10;1(1):1-9.*
4. *4. UK Reproducibility Network Steering Group. Systematizing Effective Practice, Embedding It in Standard Practice. Patterns. 2020 Nov 13;1(8):100151.*

III Best practice approaches for an events research programme

i. The research programme should aim to generate the highest quality evidence based on the principles outlined above to enable performing arts, live music and sporting events to resume sustainably with minimal risk of transmission.

ii. It is anticipated that the events are low risk as the prevalence will be low and mitigation measures will be in place. As "safety", or a minimal increase in transmission is the starting point, sample sizes will need to be large to test this "safety"- or "non-inferiority"-level to be tested. Thus, results from the research programme will need to be pooled across studies to have the statistical power to address the priority questions, requiring the same or similar designs and measures for similar types of events and venues.

Importantly, at best, pooled results across pilots are likely only to be able to estimate what increase in transmission can be ruled out from attending events - not an estimate of the risk of transmission - and even then, only if appropriate control groups are defined and followed.

iii. Studies should be informed by existing theory and evidence regarding behaviour in crowds at events, its measurement and interventions to change it.

This literature is summarised elsewhere[1].

iv. Establish a living review of published and unpublished evidence, building on the rapid review underway by the rapid reviews Covid-19 team at Public Health England.

This rapid review was commissioned as part of this DCMS Commission, addressing the following two questions:

What evidence is there of COVID-19 transmission within large events and associated venues, and what factors are associated with transmission?

What are the effects of interventions designed to minimise COVID-19 transmission within large scale events and associated venues?

At the time of writing, five studies met the inclusion criteria, three describing outbreaks, one a modelling study, and one a quasi-experimental study of a large indoor event with a simulation component.

Interim results are provided in Appendix H

We recommend that DCMS commissions the rapid review team to establish this as a "living review" updated regularly, to inform the events research programme.

1. *Drury J, Rogers MB, Marteau TM, Reicher S, Stott C. Re-opening live events and large venues after Covid-19 "lockdown": Behavioural risks and their mitigations. 2021 Safety Science in press* https://psyarxiv.com/ze8by/

Appendices

Appendix A DCMS Commission

A framework for generating evidence to inform decisions on opening up group events

The Commission will result in a paper for DCMS-DHSC from EMG to inform a research programme focusing on opening events and venues with minimal transmission risk. See Appendix B for the relevant sections from Covid-19 Response – Spring 2021[1].

The objective of this will be:

- To identify the key scientific questions, and suggested prioritisation, to be addressed by pilot events within a research programme
- To outline a set of principles to guide the design and evaluation of pilot events in order to address identified questions
- To conduct a rapid review of existing literature around the reopening of events, with a particular focus on:
    a. evidence of transmission associated with events and pilots
    b. evidence of mitigation from different measures designed to reduce transmission
- To outline best practice approaches for an events research programme to ensure the ability to pool results across pilots to inform decisions on opening up group events with minimal transmission risk.

A group will be established to take forward this work, with membership outlined in Appendix A. The scope of this work will be limited to public or commercial ticketed events.

A working draft of the paper is required by 8 March 2021 to shape imminent decisions around pilot event selection.

A joint DCMS-DHSC research programme is being established, this will include the establishment of a Science Board for the Events Research Programme. This Board will be informed by the paper and ensure the implementation of its recommendations:

- The Chair of the Science Board would be independent of DCMS and any of the Pilots.

- The Science Board would be set within the wider governance structure within DCMS and DHSC for the Events Research Programme.

- Events will need to be approved by the Science Board to ensure that they are conducted within an evaluation framework to generate evidence of sufficient quality

[1] https://www.gov.uk/government/publications/covid-19-response-spring-2021

Appendix B Membership of Working Group

Theresa Marteau (EMG-SPI-B) *co-chair*
John Edmunds (SPI-M) *co-chair*

Allan Bennett (EMG-PHE)
John Drury (SPI-B)
Stephen Reicher (SPI-B)
Brooke Rogers (SPI-B and SAGE)
Shaun Fitzgerald (EMG)
Malcolm Cook (Loughborough University)
Adam Kucharski (SPI-M)
Mark Lloyd (CO)
James Calder (Imperial College)
Phil Blythe (CSA DfT)
Iain Buchan (University of Liverpool)
Matthew Boulter (Clinical Lead, Project Encore, Test and Trace)
Dean Creamer (DCMS, Director, Commonwealth Games)
Michael Parker (SAGE)

Appendix C Relevant Sections from COVID-19 Response - Spring 2021

The government published 'COVID-19 Response - Spring 2021'[2] on the 22nd February, this document sets out a roadmap out of the current lockdown for England.

Relevant sections of the document, that pertain to this work are included below. Events pilots are due to begin as part of Step 2, no earlier than 12 April. For reference Step 3 will take place no earlier than 17 May and Step 4 no earlier than 21 June, with at least five weeks between the preceding step and following a further review of the data and the four tests. Government intends to announce one week in advance whether restrictions will be eased as planned. Steps 1-4 and the corresponding proposed allowed activity can be found in Appendix C.

Step 3 *(pg 36-37)*

120. In Step 3, all but the most high-risk sectors will be able to reopen. In all sectors, COVID-Secure guidance will remain in place and premises must not cater for groups larger than the legal limits. Sectors which will reopen include:

a. **Indoor hospitality**, with no requirement for a substantial meal to be served alongside alcoholic drinks, and no curfew. The requirement to order, eat and drink while seated ('table service') will remain;
b. **Remaining outdoor entertainment**, such as outdoor theatres and cinemas;
c. **Indoor entertainment**, such as museums, cinemas and children's play areas;
d. **Remaining accommodation**, such as hotels, hostels and B&Bs;
e. **Adult indoor group sports and exercise classes**; and
f. **Some large events, including conferences, theatre and concert performances and sports events**. Controlled indoor events of up to 1,000 people or 50% of a venue's capacity, whichever is lower, will be permitted, as will outdoor events with a capacity of either 50% or 4,000 people, whichever is lower. The Government will also make a special provision for large, outdoor, seated venues where crowds can be safely distributed, allowing up to 10,000 people or 25% of total seated capacity, whichever is lower. In addition, pilots will run as part of the Events Research Programme to examine how such events can take place without the need for social distancing using other mitigations such as testing (see paragraphs 132 to 134).

Socio-economic analysis of Step 3 (*pg 38*)

- The arts, entertainment and recreation sector (excluding sports, amusement and recreation) has been hit very hard by the pandemic. Pre-COVID-19, this sector was worth £18.3 billion GVA UK wide (£15.5 billion in England) and had 473,000 jobs (400,000 in England). GVA output in the arts, entertainment and recreation sector as a whole compared to February fell by 46% in April, and subsequently to 33% in November; in no month since March has output been above 77% of pre-pandemic levels[3]. The sector as a whole has also had a high take-up of the furlough scheme, with 455,000 furloughed at peak in spring, and 293,000 furloughed at the end of November. Between 25 January and 7 February, 44% of businesses in the arts, entertainment and recreation sector have paused trading.[4] Reopening these sectors can allow these businesses to recover revenues and bring back employees.
- The relaxation of social contact rules is likely to have a positive impact on wellbeing as people will be able to socialise and meet friends and family indoors for the first time in several months. Restrictions on social contact have had adverse mental health and wellbeing impacts.

Step 4 (*pg 39*)

[2] https://www.gov.uk/government/publications/covid-19-response-spring-2021

[3] ONS, GDP monthly estimate, UK: December 2020

[4] ONS, Business insights and impact on the UK economy: 11 February 2021.

127. With appropriate mitigations in place, by Step 4, the Government aims to:
   a. **Remove all legal limits on social contact**, publishing accompanying guidance on how best to reduce the risk of transmission and protect ourselves and loved ones;
   b. **Reopen the remaining closed settings, including nightclubs and enable large events, including theatre performance**s, above the Step 3 capacity restrictions, subject to the outcome of the scientific Events Research Programme (set out in paragraphs 132 to 134) and potentially using testing to reduce the risk of infection, subject to further evaluation; and
   c. **Remove all limits on weddings and other life events**, subject to the outcome of the scientific Events Research Programme.

COVID status certification *(pg 40)*

130. COVID status certification involves using testing or vaccination data to confirm in different settings that people have a lower risk of transmitting COVID-19 to others.

131. The Government will review whether COVID-status certification could play a role in reopening our economy, reducing restrictions on social contact and improving safety. This will include assessing to what extent certification would be effective in reducing risk, and the potential uses to enable access to settings or a relaxation of COVIDSecure mitigations. The Government will also consider the ethical, equalities, privacy, legal and operational aspects of this approach and what limits, if any, should be placed on organisations using certification. It will draw on external advice to develop recommendations that take into account any social and economic impacts, and implications for disproportionately impacted groups and individuals' privacy and security. The Government will set out its conclusions in advance of Step 4 in order to inform the safe reopening of society and the economy.

Large events *(pg40)*

132. DCMS and the Department for Business, Energy and Industrial Strategy have been working with representatives from industry and civil society to explore when and how events with larger crowd sizes, less social distancing or in settings where transmission is more likely (i.e. indoors), will be able to return safely. This includes sports events, music festivals and large weddings and conferences.

133. Over the spring the Government will run a scientific Events Research Programme. This will include a series of pilots using enhanced testing approaches and other measures to run events with larger crowd sizes and reduced social distancing to evaluate the outcomes. The pilots will start in April.

134. The Government will bring the findings from across different sectors and different settings to determine a consistent approach to lifting restrictions on these events. Depending on the outcome of this work, the Government hopes to be able to lift restrictions on these events and sectors as part of Step 4.

Appendix C - Steps and Corresponding Planned Easing of Restrictions *(pg 43-44)*

STEP 1
8 March – 29 March

EDUCATION
8 MARCH
- Schools and colleges open for all students
- Practical Higher Education courses

SOCIAL CONTACT
8 MARCH
- Exercise and recreation outdoors with household or one other person
- Household only indoors

29 MARCH
- Rule of 6 or two households outdoors
- Household only indoors

BUSINESS & ACTIVITIES
8 MARCH
- Wraparound care, including sport, for all children

29 MARCH
- Organised outdoor sport (children and adults)
- Outdoor sport and leisure facilities
- All outdoor children's activities
- Outdoor parent & child group (up to 15 parents)

TRAVEL
8 MARCH
- Stay at home
- No holidays

29 MARCH
- Minimise travel
- No holidays

EVENTS
- Funerals (30)
- Weddings and wakes (6)

STEP 2
No earlier than 12 April

At least 5 weeks after Step 1

EDUCATION
- As previous step

SOCIAL CONTACT
- Rule of 6 or two households outdoors
- Household only indoors

BUSINESS & ACTIVITIES
- All retail
- Personal care
- Libraries & community centres
- Most outdoor attractions
- Indoor leisure inc. gyms (individual use only)
- Self-contained accommodation
- All children's activities
- Outdoor hospitality
- Indoor parent & child groups (up to 15 parents)

TRAVEL
- Domestic overnight stays (household only)
- No international holidays

EVENTS
- Funerals (30)
- Weddings, wakes, receptions (15)
- Event pilots

STEP 3
No earlier than 17 May

At least 5 weeks after Step 2

EDUCATION
- As previous step

SOCIAL CONTACT
- Maximum 30 people outdoors
- Rule of 6 or two households indoors (subject to review)

BUSINESS & ACTIVITIES
- Indoor hospitality
- Indoor entertainment and attractions
- Organised indoor sport (adult)
- Remaining accommodation
- Remaining outdoor entertainment (including performances)

TRAVEL
- Domestic overnight stays
- International travel (subject to review)

EVENTS
- Most significant life events (30)
- Indoor events: 1,000 or 50%
- Outdoor seated events: 10,000 or 25%
- Outdoor other events: 4,000 or 50%

STEP 4
No earlier than 21 June

At least 5 weeks after Step 3

All subject to review

EDUCATION
- As previous step

SOCIAL CONTACT
- No legal limit

BUSINESS & ACTIVITIES
- Remaining businesses, including nightclubs

TRAVEL
- Domestic overnight stays
- International travel

EVENTS
- No legal limit on life events
- Larger events

Appendix D Events within DCMS Remit

Performing Arts and Live Music Indoor Venues

- Large Scale Theatre eg. play at the Palladium
- Arena Scale Performance eg. band at the O2
- Medium Theatre eg. musical at regional theatre
- Small Theatre eg. Southwark Playhouse
- Typical Comedy Venue eg. The Frog and Bucket
- Grassroots Music venue – band venue, unseated
- Grassroots Music venue – band venue, seated
- Classical music or opera - small scale eg. St John's Smith Square
- Dance or opera - large scale eg. Royal Albert Hall
- Medium Concert Hall (with orchestra pit) e.g. Cadogan Hall, Liverpool Philharmonic Hall
- Choir in a cathedral
- Choir in community hall

Performing Arts and Live Music Outdoor Venues

- Small multiday greenfield music festival (5,00-10,000 capacity)
- Medium multiday greenfield music festival (10,000-30,000 capacity)
- Large multiday greenfield music festival (30,000+ capacity), e.g. Glastonbury
- Urban and metropolitan music festivals (may include mix of indoor/ outdoor venues)
- Smaller Festival e.g County Show
- Outdoor Concerts e.g Hampton Court
- Outdoor theatre e.g Minack Theatre Cornwall

Sporting Indoor Venues

- Large Arena venues e.g Indoor Athletics at Birmingham, Cycling at Glasgow
- Smaller Arena Events e.g Ice Hockey at Nottingham Ice Centre
- Theatre Size Events e.g Snooker at Crucible

Sporting Outdoor Venues

- Very Large unseated events e,g Horserace meetings
- Large Distributed events e.g Golf Tournaments
- Very Large Seated stadia e.g Premier League football
- Large Unseated stadia e.g Lower League football

Business Events

- Large Outdoor Trade Shows e.g. Air trade show (https://www.aeroexpo.co.uk/)
- Large Indoor Exhibition Events e.g British Motor Show (https://thebritishmotorshow.live/)
- Hotel Based Conferences e.g. Academic/Business Conference
- Smaller Training Events

Appendix E List of published DCMS guidance

Working Group	Guidance
Broadcasting and Film	TV production guidance: managing the risk of coronavirus (COVID-19) in production making
	Working safely during COVID-19 during film and high-end TV production
	APA Covid-19 Shooting Guidelines
	Music Production
Heritage	Archaeological finds: metal detecting, field-walking, mud-larking
	Working safely in heritage locations in England during coronavirus (COVID-19)
Sport	Elite Sport stage 1: return to training
	Elite Sport stage 2: return to training: group/squad training protocols
	Elite Sport stage 3: return to domestic competition
	Elite Sport stage 4: return to cross-border (international) competition
	Elite sport stage 5: return to competition - safe return of spectators
	Coronavirus (COVID-19): grassroots sports guidance for safe provision including team sport, contact combat sport and organised sport events
	Coronavirus (COVID-19): grassroots sports guidance for the public and sport providers
	Providers of grassroots sport and sport facilities
	Return to competitive recreational cricket
	Return to competitive grassroots football
	Volleyball

	England Lacrosse: return to play
	Rugby League
	Rugby Union
	Hockey
	Basketball: return to play
	Netball
	Gaelic sports
	Goalball
	British gymnastics
	Ice Hockey
	Rollersports
	Rowing
	Handball
	British American football
	Great Britain wheelchair rugby
	Wheelchair Basketball
Youth	Youth centres and clubs
Youth / Entertainment and Events	Fundraising activities
Visitor Economy	Guidance for visitor economy workers on reopening after 4 July ● Outdoor Events - added to Visitor Economy guidance

	Working safely during Covid-19 in hotels and other guest accommodation
	Hospitality: Guidance for reopening hospitality businesses, including hotels and accommodation, and restaurants and pubs (the latter a BEIS lead) ● Bowling - added to the Hospitality guidance
	Business Events: All Secure Standard
	Casinos
	Betting shops
	Bingo halls
	Arcades
Museums and Galleries	Coronavirus (COVID-19): NMDC good practice guidance on the reopening of museums after 4 July
Libraries	Library services
Entertainment and Events	Performing Arts
	Cinemas (indoor and drive-in/outdoor cinemas)
	Outdoor events and festivals (e.g. outdoor music concerts)
Soft play	Indoor Play Guidance
Defra guidance	Reopening of zoos and aquariums
Volunteering	Enabling safe and effective volunteering during the coronavirus pandemic

Appendix F Outline for a randomised trial for large outdoor event or events

Setting: Outdoor event – either large sporting match or stadium sized, outdoor, concert
Trial type: A non-inferiority individually randomised trial
Research Question: Does attending a large outdoor event increase participants risk of SARS-CoV-2 infection?
Intervention: Attending or not attending event.
Outcome: Testing positive for Covid 5-10 days after the event.
Randomisation: Randomise potential attendees to either attend the event or not.
Exclusion criteria: Individuals testing positive prior to the event (for both arms), children, those that are clinically shielding and pregnant women
Primary analysis:
Compare those who attended the event versus those who did not. Calculate confidence interval for risk ratio/difference and determine if this includes or excludes the non-inferiority margin.
Secondary analysis:

1. **Vaccine use:** Estimate the risk by prior vaccination status.
2. **Transport use:** Compare the likelihood of acquiring SARS-CoV-2 stratified by the transport used to get to the event.
3. **Spatial analysis:** Assess clustering of any cases at the event by allocated seat location.

Trial process

1. Participant are screened. If a football match is the event in question, potential participants will be drawn from season-ticket holders and members. This should help ensure good participation rates, particularly if individuals who complete both tests are prioritised for future match tickets or are offered a reduced price for future tickets.
2. They are randomised to attend the event or not
3. Collect baseline characteristics - (age, gender, occupation, prior SARS-CoV-2 infection, vaccination status)
4. Test all participants within 48 hours of the event using LFDs. All positive individuals are removed from both arms.
5. Participants attend or do not attend the event.
6. All participants are tested 5-10 days after the event, ideally using PCR.
7. Participant leaves study (i.e. very limited follow-up)

Sample size calculation

10% higher risk

Sample size calculation for true relative effect of 1.1 (10% higher)

	Events in control arm		
	1 in 400 0.25%	1 in 600 0.16%	1 in 1250 0.08%
Relative risk increase to rule out			
3 * more	5,502	8,628	17,308
2.5 * more	10,134	15,888	31,876
2 *more	24,514	38,442	77,120
1.5 * more	124,078	194,576	390,404

Assumptions

Power: 90%

Type 1 error: 5%

Pre-event test sensitivity: 75%

Total dropout: 28%

Appendix G Measures

(a) Biological

2. Data collection on enrolment via ticketing App
    a. Age
    b. Vaccination status (*not if via data linkage from testing site enrolment*)
    c. Symptoms (WHO definition)
    d. Household contacts with case
    e. Household contacts with anyone who has symptoms (WHO definition)
    f. Repeat symptom screening questions on day of event via app
    g. Seat position
    h. Travel
    i. Number of people in party from the same household.

3. Inclusion criteria
    a. Adults (>=18 years)
    b. Not shielded or in a household with someone shielding / specific at-risk groups
    c. Agree to pre-screening questionnaire with consent/pilot information pack

4. Testing, consent and data linkage
    a. Testing to identify infectious individuals pre-event
        i. Two lateral flow tests, one within 24h the other within 5 days of indoor event
        ii. One lateral flow test within 24h of an outdoor event
    b. Testing to identify infected individuals linked to transmission at the event
        i. Quantitative PCR 5-7 days after the event – this could be by a home test supplied on exiting venue and date stamped with a text reminder on the test day – return rate may be poor without incentive – alternatively supply PCR to asymptomatic testing centres
        ii. Beyond 7-10 days transmission may be after the event – trade off between detecting slow incubators and minimising inclusion of post-event transmissions
    c. Asymptomatic testing sites need to enrol participants into trials/studies
        i. Consent and pilot/trial/study information packs
        ii. Positive COVID test within past 90 days
        iii. Event specific screening questions
        iv. Data linkage e.g. www.cipha.nhs.uk with vaccination and testing data for local population

5. Further considerations
    a. Relative sensitivity of home-test option with serial use and guidance by app/video to consider when available.
    b. Maximum throughput of testing centres around the venues to be factored into event size selection vs power to generate essential evidence.
    c. PCR +ve 5-7 days after event may be from pre/post-event transmission – reflect on Ct

d. Local public involvement around venues essential to weighing acceptable risks/benefits and co-creating effective risk mitigations and communications
e. Transmission and risk mitigation (through testing) chains exist across events – to factor into multi-event passporting and critical masses of testing
f. Incentives for testing among controls and follow-ups need co-creating with target audiences

(b) Environment

i. Ventilation and Environment

It is advisable to provide an evidence base for understanding the physical characteristics and occupancy levels and their roles in determining the level of risk in a transmission event. This is to help inform policy makers and other stakeholders as to which venue types, ventilation characteristics and attendee numbers might be appropriate at any given time.

The physical environment of a venue can be an important factor in terms of influencing the likelihood of a transmission event if one or more infectious persons are present. Studies should be designed to help us understand the role of particular physical characteristics in contributing to the overall risk of transmission.

The study should enable comparisons of

1. rate of provision in total of fresh air to occupied spaces
2. rate of provision in total of air recirculated from one space to another
3. rate of provision of fresh air per person to occupied spaces
4. rate of provision of air per person recirculated from one space to another
5. air change rate (rate of supply of fresh air / volume of space)
6. temperature, humidity, CO_2 in each zone measured before, during and after a performance
7. type of filtration for any mechanically ventilated spaces
8. transient airflow patterns and changes in ventilation rate (note that these could be significant for some naturally ventilated spaces)
9. Height of space
10. Mixing vs displacement ventilation to provide an indication of dilution characteristic
11. Number of people and seating layout
12. Clustering of people flow (‘bottle necks’) and dwell time
13. Number and duration of intervals
14. Duration of each performance half/Act
15. Degree of ventilation purging (during intervals, between performances and before performances)

Points 1-4 should include verification, possibly through re-commissioning or CO2 decay method.

Benchmarks

The appropriate thresholds for categorising environments as – for example - excellent, good, satisfactory and unsatisfactory - are uncertain. A starting point in terms of ventilation rate might be to refer to current building regulation standards where 10l/s/person is a value deemed appropriate as a minimum for extended periods for performance venues. This is equivalent to a steady state carbon dioxide concentration of ~1000ppm. However, if the performances are less than an hour, it must be stressed that the categorisation of an appropriate (instantaneous) ventilation rate is still the subject of research, and hence should be explored within this study if there are spaces which have ventilation rates lower than 10l/s/person.

ii. Environmental Sampling for SARS-CoV-2 RNA screening

Once a venue is re-opened, it is expected that LFD testing of attendees will be carried out before the event. If pre-event screening is carried out successfully and national incidence is low, it is likely that the numbers of infected persons attending the event will be very low. Therefore, any viral shedding into the environment will be minimal and any environmental sampling for SARS-CoV-2 will be expected to find very low levels of RNA, possibly below detection limits. This means that if environmental sampling is to be undertaken it should be carried out using methods with the lowest detection limits *i.e.* high volume sampling, wide area surface sampling, concentrated waste water samples. Detection limits would need to be demonstrated and if no RNA detected then results should be expressed as less than the detection limit. It will be important to ensure that any SARS-CoV-2 RNA detected is not "historical" so any venue should be extensively sampled prior to the event in order to determine background levels.

Wastewater sampling
Wastewater sampling should be considered for larger events where access to a waste water sewer is possible. If undertaken, then it is probably best for this to be carried out by teams already working in this field who have appropriate equipment and expertise. For outdoor events the effluent from portable toilet facilities could be monitored.

Surfaces
Commonly touched surfaces such as door handles, toilet areas, hand sanitiser dispensers could be sampled using swabs or sponges. This could be done on a regular basis during the course of an event as well as afterwards prior to cleaning.

Air
In indoor events, it may be possible to detect SARS-CoV-2 RNA in the air. However, this will require a high volume of air to be sampled. This could be done using specialist high volume samplers or potentially by analysing ventilation system surfaces or pre-filters. Air sampling of pinch points such as entrances or exits could also be undertaken
If there are activities which are potentially associated with an increased risk of disease transmission (i.e singing, shouting) then air sampling could focus on such activities.

Simulants
While picking up SARS-CoV-2 RNA may be unlikely in times of low incidence of infection, it may be possible to use indicators of human derived microbial contamination to assess

efficacy of mitigations such as ventilation or cleaning. These could include other respiratory viruses or respiratory tract bacteria for the air and surfaces.

(c) Behaviours that affect risk of transmission at events

Behaviours that affect risk of transmission at events include those that occur at the event, as well as those occurring before and after, particularly travel to and from the event and gathering before and afterwards (SPI-B August 2020; SPI-M August 2020; Drury et al. 2021). These include minimising contact between households, maintaining a physical distance from others not in the same household, limiting close contact with others to less than 15 minutes, particularly in indoor and poorly ventilated settings, wearing face coverings, not sharing food, drink and other items and hand hygiene.

However, it is also important to stress that the nature of risky behaviours will differ between events as a function of the groups involved. For instance, while drug taking and physical intimacy may be more common at a rock concert, at a religious gathering risks are more likely to revolve around specific ritual practices (Hopkins & Reicher 2017; Hopkins & Reicher 2021). Consequently, before designing interventions to address risky behaviours, it is necessary for any given type of event to first map the behaviours that might affect risk of transmission.

Behaviours of those unable to attend events is also important when assessing the population-level effects of events but is outside of the scope of this paper.

Many of these behaviours mediate the effect of some of the mitigation measures designed to reduce transmission at large events. They may be used to understand how mitigation measures – such as altering flows into and out of venues – have their effects. They may also be used as a surrogate outcome measure when the power of a study is too low to assess transmission risk.

Measures of these behaviours need to be based on direct observation, preferably automated. These can be supplemented by qualitative studies and questionnaire-based measures to generate a fuller understanding of processes underlying people's behaviour, their experiences of these events, and the effectiveness of interventions designed to minimise transmission of the virus (Drury et al 2021).

i. Observational measures of behaviours at events

Below are examples of observational measures for key behaviours at events.

Physical distancing

Physical distance in crowds can be quantified using images from cameras placed around and inside venues placed to provide different views (Pouw 2021; Su 2021; Ahmed 2021). In spaces where this is not possible, head counts per metre^2 can be made to estimate the density at live events using overhead cameras (Still 2019). Ticket codes might be used to distinguish distances between members of the same household and others.

The distance between two participants and the time spent at this distance can be measured using wearable devices provided at entry to a venue and worn around participants' necks during the event. Such devices, combining Bluetooth and ultra-wide band radio technology, were used in a recent evaluation of an indoor live music event (Moritz 2020).

Wearing face-coverings

The proportion of participants wearing face-coverings at an event can be estimated using images from cameras with automated analysis (eg Nagrath 2021) or manual coding (Chen 2020; Liebst 2021). Images can also be used to estimate the extent to which masks are worn appropriately.

Hand hygiene

Hand hygiene can be measured by volume of hand-sanitiser and soap dispensed at venues (Cowling 2009; Judah 2009). Use of personal hand sanitisers is unlikely to be measurable.

Sharing food, drink and other items

Images used to estimate physical distancing and mask wearing can also be coded to estimate the extent to which attendees share food (*eg* crisps), drink (drinking from the same bottle or can) and other items (*eg* scarves). Although, such behaviours may be more common amongst members of the same household it is very unlikely that it would be practical to distinguish this.. Other forms of sharing (e.g. cosmetics) may be more difficult to observe given that they occur in more intimate spaces (e.g. rest rooms).

Shouting, chanting and singing

The extent to which people vocalise during events can be studied using images. Aggregate loudness can be measured using microphones in fan areas.

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ii. measures based on surveys and qualitative studies

Before-after measures to assess learning and change:
A combination of quantitative and qualitative measures can generate insight into (1) public understandings and perceptions of risk, (2) knowledge of symptoms, (3) beliefs about transmission, and (4) perceived efficacy of measures. These variables are recognised as playing an important role in increasing or decreasing the likelihood of members of the public adhering to protective health behaviours across a range of risk events (e.g. shelter in place; Run, Hide, Tell; Hands, Face, Space) (Rogers, Amlôt & Rubin, 2013; Pearce et al., 2019; Michie et al., 2020; Denford et al., 2021) and influenced by factors such as (1) pre-existing and current relationships with event organisers and authorities, as well as (2) perceptions of fair treatment (Drury et al., 2021), both of which also affect adherence and should be measured..

Before and after measures identify existing public levels of understanding, perceptions and beliefs, intended behaviours, and perceived group norms (e.g. around distancing, hand-hygiene) prior to attending an event, and test the impact of interventions such as pre-event communication, verbal and visual guidance, and identity framing in transit to, during, and after the event. Additional understanding of a range of factors will better enable evidence-based development (including co-design) and targeting of interventions designed to inform protective behaviours at events.

Understandings and perceptions of risk
Previous experience of or awareness of risks informs public understanding of and responses to novel risks. For example, in a hypothetical radiation scenario, participants reported that lack of adherence to protective health guidance (e.g. unnecessary attendance at a monitoring or health care facility) was informed by public perceptions about the likelihood of exposure and pathways to exposure. Misperceptions about the likelihood of contamination, routes of exposure, lack of familiarity with exposure devices, and reliance upon analogies with well-known radiation events such as the Chernobyl accident led to increased perceptions of risk, higher levels of worry, and increased intention to engage in behaviours that might be detrimental to ongoing public health efforts. Additionally, members of the public labelled a realistic, feasible event as a scare story when their analogies failed to their public expectations. Fortunately, targeted communication was shown to alter both types of misunderstanding by changing understanding of the nature of an exposure device to create more realistic perceptions of risk and decreased intentions to attend a monitoring facility unnecessarily (Pearce et al., 2013).

Similar trends can be seen in public responses to real-world infectious diseases. Specifically, previous knowledge or experience of infectious disease can shape public understanding of novel infectious diseases and willingness to engage in preventative protective health behaviours. This was seen in the public response to the Zika virus outbreak in Guatemala in 2016. Public conceptualisation of Zika as another mosquito-borne disease led them to overlook the potential of the virus to be transmitted sexually (Southwell et al., 2020).

Perceived effectiveness of measures

Willingness to follow public health advice is also influenced by perceived risk, trust, response efficacy, self-efficacy, and response costs. Protection Motivation Theory posits that protective behaviours are more likely to be adopted when there are high levels of perceived personal risk, response efficacy, and self-efficacy, alongside low response costs. Coping appraisals (perceived response efficacy + perceived self-efficacy - costs) have a greater influence over behavioural intention than threat appraisal (threat severity + personal risk). Successful health communication will target coping appraisals to increase the likelihood of members of the public engaging in protective behaviours (Maddux & Rogers, 1983; Floyd, Prentice-Dunn, & Rogers, 2000; Pearce et al., 2013)

Other dimensions

These include the behaviour of event-related role models such as players and managers, perceived fairness of treatment by event organisers, and meta-perceptions of norms for, for example, distancing and wearing of face-coverings (Drury et al., 2020, 2021):

a. Relationship with organizers/ authorities
b. Fair treatment by organizers/ authorities
c. Behaviour of 'role models'
d. Meta-perception of norms (for distancing, masks, hand-hygiene)

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Appendix H Interim results of rapid review

COVID-19, events and venues: data extraction [draft]

Review questions

1. What evidence is there of COVID-19 transmission within large events and associated venues, and what factors are associated with transmission?
2. What are the effects of interventions designed to minimise COVID-19 transmission within large scale events and associated venues?

- A **literature search** was completed on 26 February 2021 to identify primary evidence related to these questions and meeting the inclusion criteria. We searched Medline, Embase, medRxiv preprints and WHO COVID-19 Research Database.
- Main **inclusion criteria**: primary studies reporting on large-scale event attendance (and associated venues) and COVID-19 transmission. Large scale was defined as >100 attendees and included performing art, live music, sport events and business events held in indoor or outdoor venues. See protocol for complete table of inclusion and exclusion criteria.
- **Search results**: 1,949 records were screened by title and abstract. Of these, 82 full-text articles were assessed for eligibility and 5 (reported on 4 events) met the inclusion criteria (see draft data extraction in Annex 1). Note that these are early results and subject to change as duplicate screening still need to be performed.
- Ten additional articles have been identified that did not meet the inclusion but may provide useful evidence and several studies reported outbreaks within relevant settings with no further investigation (see Annex 2).
- **The 5 articles (reporting on 4 events) identified (see Annex 1 for more details):**
    i. Live concert (1,212 participants) in indoor setting: The Risk of Indoor Sports and Culture Events for the Transmission of COVID-19 (Restart-19) (preprint)
    ii. Live concert in 8 different concerts in live music venues (50 to 100 attendees each):
        - Assessment of SARS-CoV-2 transmission among attendees of live concert events in Japan using contact-tracing data
        - Cluster of Severe Acute Respiratory Syndrome Coronavirus 2 Infections Linked to Music Clubs in Osaka, Japan
    iii. Business conference: Phylogenetic analysis of SARS-CoV-2 in Boston highlights the impact of superspreading events
    iv. Sporting event at stadium: Modelling the relative risk of SARS-CoV-2 infection to inform risk-cost-benefit analyses of activities during the SARS-CoV-2 pandemic
- **Next steps:** The list of included studies will be checked and finalised. The electronic search now needs to be supplemented with scans of references lists and contact with experts to look for additional studies. The data extraction will be finalised and the quality of the included studies will be assessed. A narrative synthesise will be provided.

Contact: Covid19Evidence@phe.gov.uk

Annex 1: Data extraction

Reference	Study design	Methods	Key findings
Moritz et al, 2020 The Risk of Indoor Sports and Culture Events for the Transmission of COVID-19 (Restart-19) **PREPRINT** (website of the project: https://restart19.de/en/the-project/)	Study type: semi-experimental study (with a simulation component) Objective: to investigate COVID-19 transmission risk during an experimental indoor mass gathering event (MGE) Setting: live concert under experimental conditions; Leipzig arena (indoor), Germany Study period: 22 August 2020 Participants: n=1,212 (18-50 years old; no obesity and no pre-existing conditions). All participants tested for COVID-19 before the event (positive were excluded)	3 components to the study: • 3 different scenarios (based on different hygiene concepts) experimentally assessed • aerosol distribution of potential infectious participants simulated • results of the experiment and aerosol distribution combined for an epidemiological simulation (individual based model) On arrival, participants equipped with contact tracing device, N95 masks and hand sanitizers. Intervention: 3 different scenarios: • S1: as pre-pandemic (2 main entrance/exit without restriction, no space between seats) • S2: moderate measures (arena divided in 4 quadrants, each with its own entrance/exit, participants restricted to their quadrant, checkboard pattern seating) • S3: strong measures (8 quadrants, pairwise seating with 1.5m in-between seats)	Experimental results - High numbers of contacts during entry/exit to setting but few last ≥15min; nearly all contacts during the concert itself last ≥15min. - New contacts accumulating during all event in scenario 1, limited to entry in scenarios 2 and 3. - Mean (±SD) total number of contacts: • S1: ≥15min: 8.9±3.5; ≥5min: 14.1±5.2 • S2: ≥15min: 4.7±1.9; ≥5min: 6.1±2.4 • S3: ≥15min: 1.3±0.9; ≥5min: 2.2±1.5 Simulation results - Aerosol simulation: each infectious person potentially infected between 10 and 108 participants (= exposed participants) depending on ventilation conditions. For a given ventilation condition, number of exposed participants was reduced in scenarios 2 and 3 compared to scenario 1. - Estimated incidence attributed to MGE for an incidence of 100/100,000 per week and 100,000 people attending MGE each month: • S1: 2.3% • S2: 1.1% • S3: 0.4% - This is assuming good ventilation, poor ventilation system would result in increased incidence, up to 23% in worst case scenario.

Koizumi et al, 2020 Assessment of SARS-CoV-2 transmission among attendees of live concert events in Japan using contact-tracing data	Study type: outbreak investigation Setting: 8 live concerts in different venues (50-100 capacity), Japan Study period: 15-25 February 2020 Participants: mainly women 30-50 years old attend these events	Analysis of national database of contact tracing to study this outbreak.	-74 cases (PCR) that participated in at least one of these events identified; 103 cases including secondary and tertiary cases - Suspected index case: woman in her 30s who had symptoms (cough, fever etc) when attending concert on 15 February. Positive diagnostic on 28 February. - Factors that might have facilitated the spread: ● early stage of pandemic, no mitigation measures in place ● some participants attended several events - Factors that might have minimised secondary transmission: after symptom onset (= after the events), participants did not socialise and many wore face masks.
Sugano et al, 2020 Cluster of Severe Acute Respiratory Syndrome Coronavirus 2 Infections Linked to Music Clubs in Osaka, Japan	Study type: outbreak investigation Same event as Koizumi et al	Analysis of national database of contact tracing to study this outbreak. 108 cases identified (vs 103 in Koizumi et al).	- As in Koizumi et al, suspected index case was a woman in her 30s (symptomatic); infected 23 participants at the first of these events. Of these 23, 17 attended another event the day after which 4 additional people were infected. - 4 cases (asymptomatic) then went to another event and affected 2 people (2-3 days after exposure). Similarly, 4 other asymptomatic cases infected 32 people when attending another of these events 3-4 days after exposure. Another asymptomatic case infected 3 cases when attending another event only 2 days after exposure. - 72 cases had a possible exposure from attending only 1 of these events, of which 32% likely to have been infected by symptomatic index cases and 53% by asymptomatic cases.
Lemieux et al, 2021	Study type: phylogenetic investigation	- Genome sequencing of positive nasopharyngeal samples collected	Results related to the outbreak at the business conference

Phylogenetic analysis of SARS-CoV-2 in Boston highlights the impact of superspreading events	Objective: to investigate the introduction and spread of COVID-19 in the Boston area across the first wave of the pandemic Setting: community, Boston (US) Study period: March-May 2020 Participants: samples from 772 individuals	between 4 March and 9 May 2020 (including samples from confirmed early cases). - Analyses performed by constructing a phylogenetic tree. - Identification of major lineages showed major clusters happened at a business conference and at a nursing home.	- International business conference in Boston, 26-27 February. - About 100 cases associated with this event. - Genome sequenced from 28 of these cases, showing a tight phylogenetic cluster that happened in a narrow time window. - The lineage associated to the conference was the most common lineage in the dataset available to the authors, suggesting that the conference outbreak contributed to the spread of COVID-19 in the community. - About 50,000 diagnosed cases in the US might have had epidemiological link to this event by the end of the study period.
McCarthy et al, 2021 Modeling the relative risk of SARS-CoV-2 infection to inform risk-cost-benefit analyses of activities during the SARS-CoV-2 pandemic	Study type: modelling study Objective: to develop a model of infection probability for diverse range of activities Settings: activity = well-defined set of interactions with clear bounds taking place over a period of time less than a day, including attending a sporting event as a spectator Model applied to sporting events as well as other settings.	Outcome: estimation of relative risks rather than absolute risks to take into account uncertainties. Model: calculation of probability of being infected by one of the 3 main routes: 1) airborne transmission, 2) fomite transmission 3) direct transmission Data and parameters: from analyses of the Diamond Princess outbreak Assumptions for the sporting event: - Masks required - 190min game duration - Different seating arrangements, with different physical distance in-between, considered - Different scenarios for time spent entering, walking in corridors, etc	Results for example of a sporting event - Simulation based on the TD Garden Stadium in Boston (US), considering all steps of such events (entry, sitting, eating, etc). Full capacity: 13,067 - "Risk unit" is the risk of spending 1min at 1 foot from a stranger. It is used to express relative risk and therefore to compare between mitigation strategies, - Estimated relative risks with different level of attendance: ● Full stadium: 1044 risk units (of which 696 are from the seated portion). ● Half-full stadium: 335 risk units (of which 219 are from the seated portion) ● 21%-full stadium: 125 risk units (of which 77 are from the seated portion) ● 21%-full stadium, no eating or drinking: 83 risk units.

Annex 2: Potential supplementary evidence

- **10 articles (reporting on 8 events) that did not meet the inclusion criteria but may be of use:**
  - i. Severe Acute Respiratory Syndrome Coronavirus 2 Outbreak Related to a Nightclub, Germany, 2020 – epidemiological investigations of 74 cases related to 3 events in a nightclub (between 150 and 300 guests each). Excluded as no indication of whether there was live music or any type of live event.
  - ii. 2 studies reporting of an outbreak (13 cases) after bar gathering (298 attendees). Excluded as only "bar", no mention of live music or other organised events
    - Superspreading Event of SARS-CoV-2 Infection at a Bar, Ho Chi Minh City, Vietnam
    - Asymptomatic and presymptomatic transmission of 2019 novel coronavirus (COVID-19) infection: An estimation from a cluster of confirmed cases in Ho Chi MinhCity, Vietnam (preprint)
  - iii. The resumption of sports competitions after COVID-19 lockdown: The case of the Spanish football league – simulation study to assess the impact of mitigation measures (e.g. testing strategies and number of days between match on the spread of COVID-19 during a sports competition. Excluded as simulation study (and look at infection in players rather than in spectators, so unsure it would meet the criteria of 100 people)
  - iv. An Outbreak of COVID-19 Associated with a Recreational Hockey Game — Florida, June 2020 – 14 out of 22 players infected + 1 staff member. Excluded as 1) less than 100 participants and 2) unclear whether there was public attending.
  - v. Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event – 53 cases out of 61 participants. Excluded as 1) not an event but a rehearsal (= no public) and 2) less than 100 participants
  - vi. COVID-19 Outbreak Associated with a 10-Day Motorcycle Rally in a Neighboring State — Minnesota, August–September 2020 – sport events with >460,000 particpants. Excluded as 1) do not meet our definition of organised events (it is a mix of events across 10 days) and 2) report cases associated with the events in general but not to specific settings (other article on this event, but reporting more on the impact on community incidence: The contagion externality of a superspreading event: The Sturgis Motorcycle Rally and COVID-19)
  - vii. Organizing a Mass Gathering Amidst a Rising COVID-19 Public Health Crisis: Lessons Learned From a Chinese Public Health Forum in Vancouver, BC – report on the organisation of an event with 231 in-person participants that did not result in any case.
  - viii. Analysis of SARS-CoV-2 Transmission in Different Settings, Brunei – epidemiological investigation of a cluster associated with Tablighi Jama'at gathering in Malaysia. Excluded as 1) religious gathering and 2) 4-day length (sleeping at the mosque)
- **3 studies reporting on clusters and superspreading events, including in settings of interest for this rapid review, were identified but were excluded as they did not specifically study them (i.e. no epidemiological investigation, just list of events):**
  - i. Clusters of Coronavirus Disease in Communities, Japan, January–April 2020 ("The largest non–healthcare-related cluster we observed was among >30 people who attended a live music concert, including performers, audience members, and event staff.")
  - ii. Clustering and superspreading potential of SARS-CoV-2 infections in Hong Kong (The largest cluster comprised 106 cases and was traced back to a collection of four bars across Hong Kong […]Transmission to the other three bars is suspected to have occurred via a number of musicians who performed at the four venues")

iii. Mass gathering events and undetected transmission of SARS-CoV-2 in vulnerable populations leading to an outbreak with high case fatality ratio in the district of Tirschenreuth, Germany ("The most frequently reported exposures included having been guests at the small local beer tradition between 3 March and 7 March 2020 (13%), skiing vacation in Austria or Italy in February/March (11%), and the big, 1-day beer event in Mitterteich (9%))