Health Information and Quality Authority

An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

Evidence summary on activities or settings associated with a higher risk of SARS-CoV-2 transmission

18 November 2020

About the Health Information and Quality Authority

The Health Information and Quality Authority (HIQA) is an independent statutory authority established to promote safety and quality in the provision of health and social care services for the benefit of the health and welfare of the public.

HIQA's mandate to date extends across a wide range of public, private and voluntary sector services. Reporting to the Minister for Health and engaging with the Minister for Children and Youth Affairs, HIQA has responsibility for the following:

- **Setting standards for health and social care services** — Developing person-centred standards and guidance, based on evidence and international best practice, for health and social care services in Ireland.
- **Regulating social care services** — The Chief Inspector within HIQA is responsible for registering and inspecting residential services for older people and people with a disability, and children's special care units.
- **Regulating health services —** Regulating medical exposure to ionising radiation.
- **Monitoring services** — Monitoring the safety and quality of health services and children's social services, and investigating as necessary serious concerns about the health and welfare of people who use these services.
- **Health technology assessment** — Evaluating the clinical and cost-effectiveness of health programmes, policies, medicines, medical equipment, diagnostic and surgical techniques, health promotion and protection activities, and providing advice to enable the best use of resources and the best outcomes for people who use our health service.
- **Health information** — Advising on the efficient and secure collection and sharing of health information, setting standards, evaluating information resources and publishing information on the delivery and performance of Ireland's health and social care services.
- **National Care Experience Programme** — Carrying out national service-user experience surveys across a range of health services, in conjunction with the Department of Health and the HSE.

List of abbreviations used in this report

aOR	adjusted odds ratio
CI	confidence interval
COVID-19	Coronavirus disease 2019
EAG	expert advisory group
ECDC	European Centre for Disease Prevention and Control
EEA	European Economic Area
EU	European Union
HIQA	Health Information and Quality Authority
HPSC	Health Protection Surveillance Centre
HSE	Health Service Executive
HTA	health technology assessment
HVAC	heating, ventilation and air-conditioning
NPHET	National Public Health Emergency Team
RR	relative risk
RT-PCR	reverse transcription polymerase chain reaction
SAGE	Scientific Advisory Group for Emergencies
SAR	secondary attack rate
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SSE	superspreading event

UK	United Kingdom
US	United States
WHO	World Health Organization

Evidence summary on activities or settings associated with a higher risk of SARS-CoV-2 transmission

Key points

- SARS-CoV-2 is a highly infectious virus, which has caused tens of millions of cases of COVID-19, and over one million deaths, globally.
- A more thorough understanding of activities and settings that present a greater risk of SARS-CoV-2 transmission may help decision-makers to implement more targeted public health measures.
- Terms relevant to describing characteristics of SARS-CoV-2 transmission include:
    - A cluster, which is defined as two or more test-confirmed cases, among individuals associated with a specific setting, with dates of onset of illness occurring within a 14-day period.
    - Superspreading events (SSEs), which are defined as events that result in the transmission of infection to a larger number of individuals than is usual.
    - The secondary attack rate (SAR), which is the probability that an infection occurs among susceptible people within a specific setting.
    - Overdispersion, which is when the minority of infected individuals are responsible for the majority of secondary transmissions.
- Nineteen studies were included in the evidence summary; seven evidence syntheses and twelve primary research studies.
- There is consistent evidence that SARS-CoV-2 clusters predominate in household settings, and that they are associated with a higher SAR (18.1% (95% confidence interval (CI), 15.7%-20.6%)) compared with other settings (for example, estimated SAR in healthcare settings is <1%). The SAR for SARS-CoV-2 is high compared with other pandemic respiratory viruses.
- Other activities or settings where large numbers of clusters have been consistently observed include nursing homes, hospitals, meat and food processing plants, large shared accommodation, sporting activities, bars, nightclubs and restaurants, gyms, offices, cruise ships, weddings, shopping malls, prisons, mines and religious settings. Many of these settings and activities have been associated with SSEs and have seeded large numbers of cases.
- The main factors found to contribute to transmission risk include: indoor environments, crowds, and prolonged and intense contact with others. Other important factors may include the level of ventilation, speaking volume, insufficient use of face coverings, along with the viral load of the index case. In particular, activities involving dining, drinking, exercising, singing or shouting, prolonged face-to-face conversation, especially in indoor crowded

environments, were associated with an increased risk of transmission in several studies. A range of effective infection prevention and control measures may mitigate some of the transmission risk associated with these settings and activities.

- Specifically in relation to occupational settings, additional factors found to be associated with an increased risk of transmission include: working despite symptoms ('presenteeism'); higher proportions of individuals from lower socio-economic groups, ethnic minorities and those with migrant status; lack of access to hand-washing facilities; inadequate or inappropriate use of personal protective equipment (PPE); exposure to multiple clients; face-to-face contact; congregation; shared accommodation and transportation; and exposure to fomites (such as tools).
- While there is consistent evidence that the risk of transmission is substantially lower in outdoor settings, clusters in outdoor environments have been observed, particularly when there are large gatherings, limited social distancing, dense congregation, and mixing among groups.
- A retrospective cohort study included in this evidence summary estimated that 19% (95% CI, 15-24%) of COVID-19 cases seeded 80% of all local transmission, while 69% of cases did not transmit to anyone. The transmission pattern of SARS-CoV-2 appears to be highly overdispersed, with a small proportion of cases potentially seeding the majority of local transmission.
- A number of limitations need to be considered when interpreting the findings of this evidence summary. Recall and reporting biases are particular issues in relation to the investigation and reporting of SARS-CoV-2 clusters. Hence, clusters may have been over-reported in certain settings, and under-reported in others. The findings are also time-sensitive; as time progresses a different picture of where clusters occur may emerge, particularly given the wide scale adoption of testing and infection prevention and control measures.
- Ongoing, robust surveillance and contact tracing (including retrospective contact tracing or source finding) across settings is critical to identify how, where, and when clusters occur and to inform the most appropriate policy measures to control the spread of SARS-CoV-2, especially in the presence of potential overdispersion as observed with this virus.
- To mitigate the additional risk of transmission, targeted public health measures are required in settings conducive to superspreading.
- The importance of adhering to self-isolation guidelines within households should be clearly communicated given the high risk of onward transmission in this setting.

Evidence summary on activities or settings associated with a higher risk of SARS-CoV-2 transmission

The Health Information and Quality Authority (HIQA) has developed a series of evidence summaries to inform advice from HIQA to the National Public Health Emergency Team (NPHET). The advice takes account of expert interpretation of the evidence by HIQA's COVID-19 Expert Advisory Group. This evidence summary relates to the following policy topic outlined by NPHET:

> "Emerging evidence in relation to what constitutes higher risk areas, activities or workplaces in regard to transmission of COVID-19"

This evidence summary was developed to address the following research question that was formulated to inform the above policy topic:

> "What activities or settings are associated with a higher risk of SARS-CoV-2 transmission?"

Background

SARS-CoV-2 is a highly infectious virus, which has caused tens of millions of cases of COVID-19, and over one million deaths, globally.[1] The current second wave of the pandemic, across Europe in particular, is causing significant challenges for governments as they aim to re-introduce restrictive measures while protecting the local economy and the health and wellbeing of the people.[2, 3] A better understanding of activities and settings that are at increased risk of SARS-CoV-2 transmission may help decision-makers to implement more targeted public health measures.[4]

In relation to COVID-19, a cluster is defined as two or more test-confirmed cases, among individuals associated with a specific setting, with illness onset dates occurring within a 14-day period.[5] The related term, outbreak, is defined as two or more test-confirmed cases, among individuals associated with a specific setting, with illness onset dates occurring within a 14-day period, when there is an epidemiological link between cases or the absence of local community transmission to explain an alternative source of infection.[5] These terms are found to be used interchangeably in the literature, though there are distinct differences between the two concepts; notably, for an outbreak, a common source of infection must be suspected.[6] For the purpose of consistency, the term cluster will be used in this report, unless it is clear that the transmission event meets the criteria for an outbreak.

The secondary attack rate (SAR) is defined as the probability that an infection occurs among susceptible people within a specific setting, and is a useful metric to understand the risk of onward transmission.[7] The emergence of SARS-CoV-2 superspreading events (SSEs), defined as events that transmit infection to a larger number of individuals than is usual, has been a feature of this pandemic.[8] It has been estimated that 80% of secondary transmissions may be caused by a small fraction (approximately 10-20%) of infectious COVID-19 cases.[9, 10] In other words, the evidence suggests that the transmission pattern of SARS-CoV-2 is potentially highly overdispersed, which is when the minority of infected individuals are responsible for the majority of secondary transmissions.[9, 11] Due to the potentially overdispersed nature of SARS-CoV-2 transmission, the infection appears to spread in clusters.[12] Therefore, a greater understanding of where and when these clusters occur may be key to controlling the pandemic.[12] The aim of this evidence summary was to provide an overview of the evidence relating to activities and settings associated with a higher risk of SARS-CoV-2 transmission.

Methods

The processes as outlined in HIQA's protocol (available here) were followed. Relevant databases of published literature and pre-print servers were systematically searched. Reports published by national and international public health agencies and governmental departments were also included, where these met the inclusion criteria. This evidence summary includes all identified relevant evidence published between 1 January 2020 and 6 November 2020.

Given the inconsistent categorisation of settings and activities across studies, a quantitative synthesis of results could not be performed. A narrative synthesis is presented, with the findings reported in line with the following three main sections, the:

1. activities and settings where clusters have occurred.
2. risk of infection associated with activities and settings.
3. secondary attack rates (SAR) associated with activities and settings.

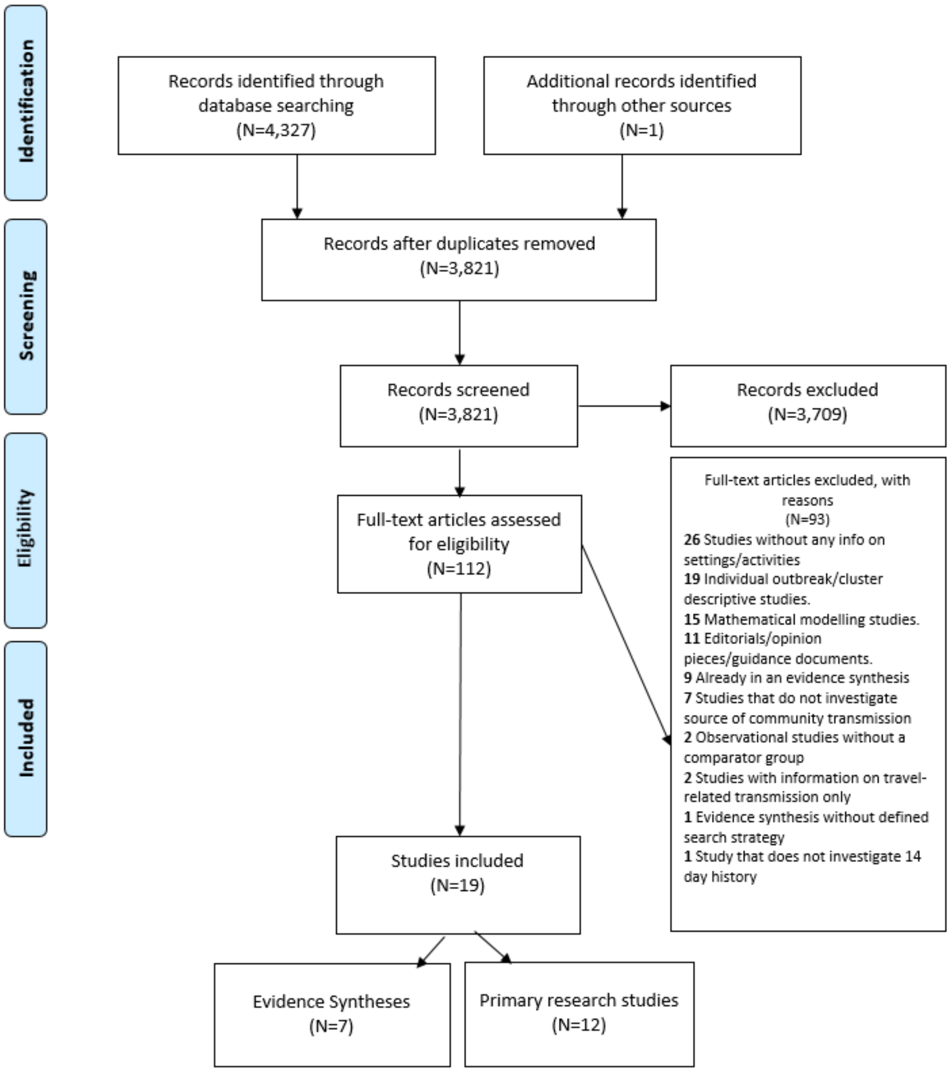
The synthesis focuses on the best available evidence (that is, systematic reviews and other forms of synthesised evidence)

Results

Search results

As shown in the PRISMA flow diagram in Figure 1, the search up until 6 November 2020 resulted in a total of 4,328 citations; following removal of duplicates, 3,821 citations were screened for relevance, with 112 full-texts assessed for eligibility and 93 subsequently excluded. At the end of this process, 19 studies were identified for inclusion in this evidence summary,[4, 10, 13-29] 18 of which were identified through electronic database searching[4, 10, 13, 15-29] and one through website searching of public health agencies and governmental departments.[14]

Figure 1. PRISMA flow diagram



Characteristics of included studies

Of the 19 included studies, seven are evidence syntheses (Appendix 1),[4, 14, 20-24] and 12 are primary research studies (Appendix 2).[10, 13, 15-19, 25-29] Specifically, three of the seven evidence syntheses are systematic reviews[4, 20, 22] (one of which also conducted a meta-analysis),[20] three are rapid reviews[14, 21, 24] and one is a meta-analysis based on a non-systematic literature review.[23] Four of the evidence syntheses examined transmission in any setting,[4, 20-22] one focused on outdoor settings and activities only,[24] one focused on occupational settings only[14] and one focused on 'every day' activities only.[23] While all evidence syntheses included academic literature, three also included media reports of clusters,[4, 14, 21] two also included government reports[14, 24] and one also included epidemiological data from a *de novo* survey of public health agencies.[14] Two of the evidence syntheses are up-to-date as of June,[21, 22] three are up-to-date as of July[4, 14, 20] and one is up-to-date as of August.[24] One evidence synthesis did not report the date of literature searching.[23] Due to the heterogeneous sources of data used, it is not possible to determine the extent to which there is overlap of clusters between evidence syntheses. However, it is likely that some of the larger clusters, which potentially received intense media and research attraction (for example, the Diamond Princess cruise ship cluster)[30] are duplicated in several of the included evidence syntheses.

In relation to the 12 primary research studies, all are observational in design; ten are retrospective cohort studies,[10, 13, 16-19, 25-27, 29] one is a case-control study,[15] and one is a retrospective cohort study with a nested case-control element.[28] Four of these studies were conducted in China,[13, 17, 25, 26] two studies each in South Korea[18, 19] and Japan,[16, 29] and one study each from the United States (US),[15] Hong Kong,[10, 16] Singapore[28] and Germany.[27] The setting and focus of each primary research study varied, but they were generally all population-based, including individuals living in the community, and involved epidemiological investigations to identify either the source of infection,[10, 13, 16, 17, 19, 26, 27] the risk of infection[15, 18, 25, 28, 29] or the rate of onward transmission.[10, 17, 18, 28] The sample size of included studies ranged from 136[13] to 7,518.[28] However, the sample sizes of included studies are not directly comparable given that six studies comprised solely COVID-19 cases,[10, 13, 16, 19, 26, 27] two studies comprised close contacts of cases,[17, 25, 28] two studies comprised individuals who had been exposed to a particular setting,[18, 29] and another study comprised COVID-19 cases and a matched control group of non-cases.[15] The month of last data collection was February in three studies,[17, 25, 26] March in two studies,[13, 27] April in five studies,[10, 16, 19, 28, 29] May in one study[18] and July in one study.[15] None of these primary research studies were included in any of the seven evidence syntheses discussed above, in line with the protocol for this evidence summary.

The activities and settings where clusters have occurred

Five of the included evidence syntheses[4, 14, 21, 22, 24] and seven of the included primary research studies[10, 13, 16, 17, 19, 26, 27] provided information on the activities and settings associated with the occurrence of SARS-CoV-2 clusters.

Evidence syntheses

The systematic review by Leclerc et al. includes literature and media reports of SARS-CoV-2 clusters that have occurred across the world.[4] This review is supplemented by an online curated database, where members of the public can suggest additional reports of clusters, and these suggestions are verified by members of the research team before being published. While the literature search was only conducted until 30 March, and the media report search was only conducted until 6 April, the online database is up-to-date as of 6 July (Table 1).

Table 1. Location of reported SARS-CoV-2 clusters, as of 6 July 2020

Setting	**Number of clusters per setting (% of total)**	**Total number of cases per setting (% of total)**	**Median cases per cluster**
Building site	4 (1.5%)	95 (0.6%)	20.5
Conference	5 (1.9%)	148 (0.9%)	10
Elderly care	21 (7.9%)	820 (5.2%)	27
Food processing plant	21 (7.9%)	3,958 (25.3%)	70
Funeral	2 (0.8%)	27 (0.2%)	13.5
Hospital	9 (3.4%)	224 (1.4%)	10
Hotel	3 (1.1%)	23 (0.1%)	7
Household	38 (14.3%)	178 (1.1%)	4
Large shared accommodation	30 (11.3%)	2,493 (15.9%)	44.5
Meal (in any setting)	17 (6.4%)	134 (0.9%)	5
Party (including Bars, Clubs)	14 (5.3%)	422 (2.7%)	16.5
Prison	6 (2.3%)	1,049 (6.7%)	171.5
Public spaces (including parks and welfare centres)	6 (2.3%)	122 (0.8%)	15
Religious	22 (8.3%)	897 (5.7%)	23
School	11 (4.2%)	374 (2.4%)	16
Ship (including cruises)	5 (1.9%)	3,689 (23.6%)	712
Shipyard	1 (0.4%)	22 (0.1%)	22
Shopping	8 (3%)	333 (2.1%)	16.5
Sport	22 (8.3%)	163 (1%)	5.5
Transport	1 (0.4%)	3 (<0.1%)	3
Wedding	4 (1.5%)	231 (1.5%)	60
Work	15 (5.7%)	235 (1.5%)	8
Total	**265**	**15,640**	**13**

Source: adapted from Leclerc et al. online database (https://bit.ly/3ar39ky)

The Leclerc review identified a total of 265 clusters from 29 countries and two cruise ships involving 15,640 COVID-19 cases. This review of clusters was restricted to the first generation of cases that acquired the infection due to transmission in a single specific setting at a specific time. Therefore, second and subsequent generations of cases were not counted. Of the 265 clusters, 38 (14.3%) occurred in a household setting, 30 (11.3%) occurred in large shared accommodation, 22 (8.3%) occurred in religious settings, 22 (8.3%) were associated with sporting activities, 21 (7.9%) occurred in care homes (including staff and residents) and 21 (7.9%) occurred in food processing plants. In terms of the number of cases per setting, food processing clusters accounted for the most people infected (n=3,958 or 25.3% of total), followed by cruise ships (n=3,689 or 23.6% of total) and large shared accommodation (n=2,493 or 15.9% of total). With regards to the median number of cases per cluster, this was found to be highest on cruise ships (n=712), followed by prisons (n=171.5) and food processing plants (n=70), indicating the significant superspreading potential of these particular settings. A key finding of this review was that the vast majority of clusters were associated with indoor settings, or at least had elements of indoor activity. Only the four building site clusters (with 95 cases) were classified as purely outdoors, this classification being performed by the review authors.[4]

A rapid review of settings linked to clusters was published by Lakha et al. in July (Table 2).[21] It expanded on the review conducted by Leclerc et al,[4] but did not restrict to the first generation of cases. The Lakha review included both academic literature as well as media reports, and searches were conducted up until 14 June 2020. It did not use an online database for retrieval of information on clusters. There is some overlap of data between Lakha and Leclerc. However, the degree of overlap is unclear due to the different time points of searches, inclusion criteria and methods of study retrieval.

A total of 616 clusters from 28 countries, involving 20,471 cases were identified (Table 2).[21] Half of all clusters occurred in household settings (n=306). The second largest setting type associated with clusters was 'entertainment and leisure', where 94 clusters were identified (15% of total). This category includes dining (n=58), sports (n=19), party (n=6), music venues, nightclub and indoor carnival (n=6) and bars (n=5). The third largest setting type associated with clusters was 'large group living' where 63 clusters were identified (11% of total). This category includes worker dormitories, shelters and refugee housing (n=26), elderly care homes (n=23), cruise liners and navy ships (n=5), hotels (n=4) and prisons (n=5).

Of the 20,471 cases, the largest single contributor was religious services, which were associated with 5,136 cases or (25.1% of total cases). Cruise liners and navy ships were associated with 3,597 cases (17.6%) and worker dormitories, shelters, refugee housing were associated with 2,286 cases (11.2%). With regards to the median number of cases per cluster, this was found to be highest on cruise liners and navy ships (n=662), followed by prisons (n=225) and processing plants, slaughterhouses and factories (n=76), indicating the significant superspreading potential of these particular settings.

Based on the findings of this review, the authors concluded that there are several main factors which can increase the transmission risk, these being:

- indoor environments
- crowded environments
- prolonged and intense contact with others.

Table 2. Documented settings associated with SARS-CoV-2 transmission clusters, correct as of 14 June 2020

Setting type	Setting detail	Reported clusters (n)	% total reported clusters	Total cluster size			Total cases (n)	% total reported cases
				Min	Median	Max		
Household (n=306, 50%)	Household	306	50	2	3	8	1,115	5.4
Entertainment and leisure (n=94, 15%)	Dining	58	9	2	18	47	1,097	5.4
	Sports – gym, fitness, table tennis, running	19	3	2	4	92	179	0.9
	Party	6	1	7	18	60	179	0.9
	Music venue, nightclub, indoor carnival	6	1	3	20	20	100	0.5
	Bar	5	1	4	10	77	112	0.5
Large group living (n=63, 11%)	Worker dorms, shelters, refugee housing	26	4	3	43	797	2,286	11.2
	Elderly care home	23	4	5	27	167	906	4.4
	Cruise liner, Navy Ship	5	1	78	662	1,156	3,597	17.6
	Hotel	4	1	3	8	13	24	0.1
	Prison	5	1	66	225	353	989	4.8
Workplace (n=54, 9.5%)	Office/meeting	29	5	4	6	30	258	1.3
	Processing plant/ slaughterhouse/ factory	12	2	3	76	534	1,843	9.0
	Conference	5	1	3	10	89	148	0.7
	Shipyard/construction site	5	1	5	22	49	117	0.6
	Call centre/mail centre	3	0.5	8	97	164	269	1.3
Public spaces (n=40, 6.2%)	Shopping/supermarket	32	5	7	13	87	588	2.9
	Outdoor market	3	0.5	25	27	163	215	1.1
	Community centre	3	0.5	10	10	10	30	0.1
	Playground	2	0.2	20	23	26	46	0.2
Religious (n=22, 3.5%)	Religious services	19	3	2	29	4,482	5,136	25.1
	Choir practice	3	0.5	53	59	102	214	1.0
Health care facility (n=14, 2%)	Healthcare facility	14	2	2	10	118	325	1.6
Educational setting (n=10, 2%)	Educational setting	10	2	2	15	133	368	1.8
Travel related (n=8, 1%)	Buses, flights and trains	8	1	2	8	30	89	0.4
Other social gatherings (n=5, 0.9%)	Funeral	1	0.2	4	4	4	4	<0.1
	Wedding	3	0.5	13	43	98	154	0.8
	Rally	1	0.2	83	83	83	83	0.4
Total		**616**	**100**				**20,471**	**100**

Source: adapted from Lakha et al.[21]

The European Centre for Disease Prevention and Control (ECDC) published a report on 11 August 2020, examining clusters and outbreaks in occupational settings in the European Union (EU), European Economic Area (EEA) and the United Kingdom (UK).[14] The report was based on a rapid review of the literature (up until 20 July), a survey of public health authorities across the EU, EEA and UK (up until 24 July) and national and media reports (up until 23 July).

A total of 1,376 clusters in occupational settings were reported, including 18,170 COVID-19 cases and 166 deaths (from n=16 reporting countries in the EU/EEA/UK). Of note, the data presented in Table 3 may relate to workers only, or else a combination of workers and patients, clients, service users, or students, as the data were inconsistently reported by different countries.

Table 3. Documented occupational settings associated with SARS-CoV-2 clusters, as of 24 July.

Setting	Number of clusters reported (%)	Total number of cases reported (%)	Number of reported deaths (%)	Number of cases within a cluster (min - max)[1]
Health and social care	836 (60.8%)	8,982 (49.4%)	128 (77.1%)	2 - 571
Hospitals	241 (17.5%)	3,298 (18.2%)	82 (49.4%)	2 - 571
Long-term care facilities	591 (43%)	5,670 (31.2%)	46 (27.7%)	2 - 342
Primary care facilities	4 (0.3%)	14 (0.07%)	0	2 - 5
Food packaging and processing	153 (11.1%)	3,856 (21.2%)	4 (2.4%)	2 - 117
Factory/manufacturing	77 (5.6%)	1,032 (5.7)	0	2 - 96
Building and construction sites	27 (2%)	402 (2.2%)	0	2 - 69
Office	65 (4.8%)	410 (2.3%)	4 (2.4%)	2 - 23
Educational facilities	22 (1.6%)	143 (0.8%)	1 (0.6%)	2 - 35
Sales and retail	22 (1.6%)	188 (1%)	6 (3.6%)	2 - 30
Military and law enforcement	29 (2.1%)	269 (1.5%)	0	2 - 50
Mines	4 (0.3%)	1,538 (8.5%)	1 (0.6%)	4 - 704
Other occupational settings[2]	79 (5.7%)	696 (3.9%)	4 (2.4%)	3 - 35
Unclassified	63 (4.6%)	682 (3.8%)	18 (10.8%)	2 - 52
Total	**1,376**	**18,170**	**166**	**2 - 704**

[1]Excludes aggregated data reported by three countries.
[2]Includes various settings such as packaging/mail distribution, transportation, bars and restaurants, churches and monasteries, fitness clubs and spas.
Source: adapted from ECDC report.[(14)]

Health and social care settings were associated with the largest numbers for each of workplace clusters (n=863, 60.8% of total), cases (n=8,982, 49.4% of total) and deaths (n=128, 77.1% of total). Within health and social care, long term care facilities were associated with the largest share of clusters (n=591, 43% of total) and the largest share of cases (n=5,670, 31.2% of total). However, more deaths occurred in the hospital setting (n=82, 49.4% of all deaths) than in other care facilities. After health and social care settings, food packaging and processing was associated with the next largest number of clusters (n=153, 11.1% of total) and cases (n=3,856, 21.2% of total). However, outside of health and social care settings, deaths were relatively uncommon. Across all clusters, the average number of cases per cluster was 13.2, with a range of 2 to 704. The largest cluster identified occurred in a mine, indicating the superspreading potential of this particular setting.

Based on this evidence, the ECDC concluded that there were certain factors associated with an increased risk of transmission in occupational settings:[14]

- indoors
- poor ventilation
- lack of physical distance
- shouting (for example, due to noisy environments)
- prolonged duration of contact (for example, due to certain work shifts)
- congregation in canteen, during breaks, changing rooms, clocking in/out
- face-to-face contact with infected patients
- lack of access to hand-washing facilities
- inadequate or inappropriate use of personal protective equipment (PPE)
- exposure to multiple clients (for example, transport workers, sales people, cleaners)
- shared, crowded accommodation (where co-workers live together in often sub-standard conditions)
- shared transportation
- exposure to fomites (for example, tools, surfaces)
- working despite symptoms, particularly for self-employed workers (that is, 'presenteeism')
- lower socio-economic, ethnic minorities and those with migrant status (with reduced access to healthcare).

Weed et al. conducted a rapid scoping review examining the evidence for outdoor transmission of SARS-CoV-2.[24] Searches were conducted up until 16 August 2020. From 14 included studies, the authors concluded that there is limited evidence of SARS-CoV-2 transmission in outdoor environments during the natural course of everyday life. However, the authors found some evidence to suggest that there is a higher risk of outdoor transmission in environments where social distancing is breached, and where the density of the gathering, the circulation of people, and the size of the gathering is increased, particularly where the gathering occurs over an extended duration of time. This could include aspects of outdoor concerts, festivals and some types of physical activity and sporting events. The authors additionally found five studies that referred to a link between weather conditions and transmission, all of which associate lower temperatures with higher transmission. All of these studies suggested at least a partial role for a behavioural effect, in which lower temperatures encourage people to spend more time indoors prior to and during the event, and hence increase the overall risk of transmission.

Based on the review findings, the authors deduced that there are three main considerations when organising events and activities that generate outdoors gatherings of people:

1. Does the event or activity prompt other behaviours that might increase transmission? (for example, communal travel, indoor congregation, or collective stays in overnight accommodation)

2. For each part of the event or activity; has density, size, circulation and duration of the crowd been considered?

3. Is rapid contact tracing possible in the event of an outbreak?

Liu et al. conducted a systematic review of academic literature examining the occurrence of SARS-CoV-2 clusters globally.(22) The search was conducted between 1 January and 15 June 2020. The authors found that of the 108 clusters identified, the majority (n=62, 57% of total) occurred in household settings. The next most common circumstance where clusters occurred was in 'indoor gatherings', where 15 clusters were identified (14% of total). The number of cases per cluster (excluding the index case) ranged from one to 112, with an average and median of 12 and seven cases per cluster. The largest cluster identified, with 112 cases, was associated with a fitness class, indicating the superspreading potential of this setting.

Primary research studies

Seven of the 12 included primary research studies investigated the source of SARS-CoV-2 transmissions.(10, 13, 16, 17, 19, 26, 27) Yang et al. conducted a retrospective cohort study, examining the occurrence of clusters in China, outside of Hubei province, between 1 January and 20 February 2020.(26) The authors found that most of the clusters (297 of 377, 79% of total) occurred in families. Meals and gatherings accounted for 39 clusters (10% of total). Of note, clusters occurring in health and social care settings were excluded from this study.

Kim et al. conducted a retrospective cohort study investigating networks of large clusters (at least 20 cases) in South Korea, between 20 January and 7 April 2020.(19) The authors found that nearly half of the cases caused by these clusters were attributable to imported cases (n=588 of 1,231 cases, 46.7% of total). Clusters associated with religious gatherings resulted in almost a quarter of all cases (n=288 of 1,231 cases, 23.4%), while clusters associated with gym facilities and nursing homes were associated with 98 cases (8%) and 76 cases (6.2%), respectively. The authors concluded that clusters with the smallest path length (that is, the fewest subsequent generations of infected cases) were all in nursing homes. While those with the longest path lengths (that is, the highest number of subsequent generations of infected cases) were connected to gym facilities and a church.

Furuse et al. conducted a retrospective cohort study in Japan, examining the occurrence of clusters (of five or more cases) in different settings, between 15 January and 4 April 2020.(16) Of the 61 clusters identified, 18 (30% of total) occurred in healthcare facilities, 10 (16% of total) occurred in social care facilities and 10 (16% of total) occurred in bars and restaurants. Workplaces, music-related events and gyms were associated with eight, seven and five clusters each, respectively. The authors noted that among the probable primary COVID-19 cases identified from clusters occurring outside of healthcare facilities, half (n=11/22) were 20–39 years of age, which was younger than the age distribution of all COVID-19 cases in Japan at the time. Furthermore, the authors deduced that clusters may occur under conditions of heavy breathing in close proximity, such as singing at karaoke parties, cheering at clubs, having conversations in bars, and exercising in gyms.

Jia et al. conducted a retrospective cohort study in Fuzhou, China, investigating the risk of infection for close contacts of cases in different settings and situations, between 22 January and 29 February 2020.(17) Thirteen cluster events were identified that resulted in the infection of 24 close contacts. Ten of these clusters were associated with households (76.9% of total), two were associated with workplaces (15.4% of total) and one was associated with a care home (7.7% of total).

Adam et al. conducted a retrospective cohort study in Hong Kong between 23 January and 28 April 2020, with the aim of estimating the potential for superspreading events (SSEs).(10) The largest cluster comprised 106 cases and was traced back to a collection of four bars across Hong Kong, but the original source could not be determined. This single outbreak accounted for 10.2% (n=106) of all cases in Hong Kong during the study period (n=1,038). This cluster comprised at least one SSE. Weddings were associated with a cluster of 22 cases and linked to two SSEs. A temple in Hong Kong was associated with a cluster of 19 cases, with 12 of those linked directly to a SSE. The authors found a total of four to seven SSEs across 51 clusters in Hong Kong, resulting in a total of 309 cases. The authors estimated that 19% (95% confidence interval (CI), 15-24%) of cases seeded 80% of all local transmission, while 69% of cases did not transmit to anyone. The authors concluded that gatherings in social settings such as bars, restaurants, weddings and religious sites appear to be at increased risk of SSEs. Transmission in social settings was significantly associated with an increased number of secondary cases compared with transmission observed in family households.

Chen et al. conducted a retrospective cohort study in Tianjin, China, up until 13 March 2020 with the aim of determining potential infection sources.(13) Among the 136 COVID-19 cases, 48 cases (35.3% of total) were categorised as imported cases, which were the majority of early cases. A total of 43 cases (31.6% of total) were found to have an epidemiological link to a department store, and hence an outbreak with a common source was established. Additionally, 35 cases (25.7% of total) were considered as familial clusters of COVID-19 cases, while 10 cases (7.4% of total) were considered to be sporadic.

Brandl et al. conducted a retrospective cohort study investigating the potential exposures of the first 110 COVID-19 cases diagnosed in the Tirschenreuth region of Germany, between 18 February and 12 March 2020.(27) Of these 110 cases, the most frequently reported exposures included a small local beer festival (n=14, 13%), a skiing vacation in Austria or Italy (n=12, 11%), and a large, one-day beer event in Mitterteich (n=10, 9%). Three cases (2%) had been skiing and attended the smaller beer festival; one case (1%) had been skiing and attended the large one-day beer event. Twenty seven cases (25%) reported other possible exposures at large gatherings such as attending birthday parties, funerals or religious services. For 38 cases (35%), no known exposure could be determined. The authors concluded that returning ski-travellers from Austria and Italy and early undetected community transmission likely initiated the outbreak in the region, which was then accelerated by Bavarian beer festivals.

The risk of infection associated with activities and settings

Five of the 12 primary research studies estimated the risk of SARS-CoV-2 infection associated with particular activities or settings.(15, 18, 25, 28, 29) None of the included evidence syntheses estimated this risk of infection.

Primary research studies

Fisher et al. conducted a case-control study in the US, between 1 July and 29 July 2020, with the aim of investigating the relationship between exposure to specific settings and infection with SARS-CoV-2.(15) Case-patients (n=154) were symptomatic adults (18 years or older) with SARS-CoV-2 infection confirmed by reverse transcription-polymerase chain reaction (RT-PCR) testing. Control-participants (n=160) were symptomatic adult outpatients from the same health care facilities who had negative SARS-CoV-2 test results. For each case-patient, two adults with negative SARS-CoV-2 RT-PCR test results were randomly selected as control-participants and matched by age, sex, and study location. However, a matched analysis could not be performed due to the inability to recruit sufficient numbers of control-participants to allow for matching. Logistic regression models, adjusted for clustering, were used to assess differences in community exposures between case-patients and control-participants, with adjustment for age, sex, race or ethnicity, and the presence of one or more underlying chronic medical conditions. Case-patients were more likely to have reported dining at a restaurant (any area designated by the restaurant, including indoor, patio, and outdoor seating) in the two weeks preceding illness onset than were control-participants (adjusted odds ratio (aOR), 2.4; 95% CI, 1.5-3.8). Restricting the analysis to participants without known close contact with a person with confirmed COVID-19, case-patients were more likely to report dining at a restaurant (aOR, 2.8; 95% CI, 1.9-4.3) or going to a bar or coffee shop (aOR, 3.9; 95% CI, 1.5-10.1) than were control-participants. No significant association was found between any of the other exposures and infection with SARS-CoV-2 (exposures investigated: shopping, house gatherings with less than 10 people, house gatherings with greater than 10 people, office, salon, gym, public transport and church). An important limitation of this study was that matching of case and control patients was incomplete and hence demographic differences existed between the two groups, which could have an effect on the overall result. Additionally, unmeasured confounding is possible, such that people who may have avoided bars and restaurants may have been more risk averse in general, and so may have behaved quite differently throughout the pandemic (for example, avoiding crowds, wearing a mask), compared with those who attended bars and restaurants.

Ng et al. conducted a retrospective cohort study with a nested case-control element in Singapore, between 21 January and 3 April 2020.[28] The aim of the study was to determine the overall prevalence of SARS-CoV-2 infection and epidemiological risk factors among exposed individuals in Singapore. This study included all 7,518 close contacts of PCR-confirmed cases in Singapore, in whom complete patient data had been collected. Of the 7,518 close contacts, 1,248 had completed a questionnaire on risk factors and had either PCR or serological test (to test for antibodies to SARS-CoV-2) results. Case-patients included those close contacts who either had a positive PCR or serology test result. Control participants were those who had completed 14 day quarantine without a COVID-19 diagnosis and had a negative serology test result. Blood was sampled for serology testing at least two weeks after the 14 day quarantine period finished to allow time for seroconversion. The authors performed univariate and multivariate logistic regression to examine the association between transmission risk factors and SARS-CoV-2 infection, though it is not clear what variables were included in the multivariate models. The authors stated that they selected variables that were representative of different potential modes of SARS-CoV-2 transmission for the multivariate regression analysis and included variables with an exposure prevalence of more than 10%, a greater effect size on univariate analysis, and which were significant.

Among household contacts (n=584), exposure risk factors associated with SARS-CoV-2 infection on both univariate and multivariate analysis were sharing of a bedroom (multivariate OR, 5.38; 95% CI, 1.82-15.84), sharing of a bedroom and bathroom (multivariate OR, 5.05; 95% CI, 1.85-13.79) and being spoken to by a COVID-19 case, with the highest risk if the case spoke for 30 minutes or longer (multivariate OR, 7.86; 95% CI, 3.86-16.02). Exposure risk factors significantly associated with SARS-CoV-2 infection only on univariate analysis were having contact with more than one COVID-19 case, being a spouse or partner of a case, receiving an object handed over by a case or touching the same surface immediately after a case (or both), sharing a meal with a case, and sharing the same vehicle as a case.

Among non-household contacts (n=664), exposure risk factors associated with SARS-CoV-2 infection on both univariate and multivariate analysis were having contact with more than one COVID-19 case (multivariate OR, 3.92; 95% CI, 2.07-7.40), being spoken to by the index case for 30 minutes or longer (multivariate OR, 2.67; 95% CI, 1.21-5.88), and sharing the same vehicle as a case (multivariate OR, 3.07; 95% CI, 1.55-6.08). Exposure risk factors significantly associated with SARS-CoV-2 infection only on univariate analysis were having direct physical contact with a COVID-19 case, receiving an object handed over by a case or touching the same surface immediately after a case (or both), sharing a meal with a case, and using the same toilet as a case. The authors concluded that among both household and non-household close contacts, close physical proximity, and increased duration of verbal interaction are epidemiological risk factors for SARS-CoV-2 transmission.[(28)]

Kang et al. conducted a retrospective cohort study investigating the exposure and spread of SARS-CoV-2 associated with five major nightclubs in Seoul, South Korea, between 30 April and 6 May 2020.[(18)] The use of cell phone location data, credit card records, and lists of nightclub visitors identified 5,517 people who attended at least one of these five nightclubs during this time period. After extensive contact tracing, it was estimated that the attack rate among nightclub visitors was 1.74% (n=96 cases of 5,517 visitors). A further 150 cases were infected by these 96 cases, resulting in at least 246 cases associated with these nightclub clusters. However, the authors acknowledged that many cases and contacts may not have come forward for testing due to reported stigma associated with attending a gay nightclub in South Korea.

Takaya et al. conducted a retrospective cohort study to examine the association between exposure to nightlife activities and SARS-CoV-2 PCR test results, in Tokyo, Japan between 9 March and 26 April 2020.[(29)] The authors defined the nightlife group (n=196) as those who had worked for a nightlife business or who had visited those businesses, within one month before symptom onset. Nightlife businesses included bars and pubs, host and hostess clubs, nightclubs and live music clubs, karaoke bars and commercial sex businesses. The comparator group (non-nightlife group, n=1,321) had not worked for or visited any of these businesses in the month before symptom onset. The nightlife group's PCR positivity rate was 63.8% (n=125/196). In the unmatched non-nightlife group, the positivity rate was 15.7% (n=207/1,321). All patients in the nightlife group were matched to similar patients in the non-nightlife group using propensity scores, resulting in improved covariate balance in the matched group. After propensity score matching (for age, sex, nationality, comorbidity, severity, day of illness, exposure, overseas travel and being a healthcare worker), the proportion of positive SARS-CoV-2 PCR tests in the nightlife group remained significantly higher than that in the non-nightlife group (nightlife, 63.8%; non-nightlife, 23.0%; $p < 0.001$). The authors concluded that exposure to nightlife activities was significantly associated with positive SARS-CoV-2 PCR test results.

Wu et al. conducted a retrospective cohort study in Hanzhou, China, between 23 January and 28 February 2020.[(25)] The aim of the study was to determine the rate of secondary infections among contacts of individuals with confirmed COVID-19, according to the type of contacts, intensity of exposure and the cases' relationship with the index patient. The authors analysed data from 2,994 close contacts of 144 individuals with confirmed SARS-CoV-2 infection. Among these, 82 became infected, equating to a secondary attack rate (SAR) of 2.7%. Compared with those who had brief contact (duration not defined) with the index case, those who had shared transport with the index case, had visited the index case, or had contact with the index case in a medical institution, had 3.6 times higher odds of acquiring infection (OR, 3.57; 95% CI, 1.42-8.98) and household contacts had 41.7 times higher odds of acquiring infection (OR, 41.74; 95% CI, 17.69-98.49). Additionally, compared with those who had brief contact with the index case, those who had dined with the index case had 2.6 times higher odds of acquiring infection (OR, 2.64; 95% CI, 0.88-7.90), though this association was not statistically significant. When compared with those who had contact with the index case in a medical institution, those who had contact with the index case in a public place had 5.3 times higher odds of acquiring infection (OR, 5.32; 95% CI, 1.20-33.25), those who had contact with the index case in a workplace, educational institution or entertainment setting had 6.7 times higher odds of acquiring infection (OR, 6.67; 95% CI, 1.34-33.25), and household contacts had a 17 times higher odds of acquiring infection (OR, 17.25; 95% CI, 4.20-70.77). No information was provided as to what constitutes the various contact types. A serious limitation with this study was that confounders were not controlled for in the analysis, so their findings should be viewed with caution. Additionally the number of secondary cases may have been too small (n=82) to conduct any meaningful regression analysis, hence the very wide confidence intervals.

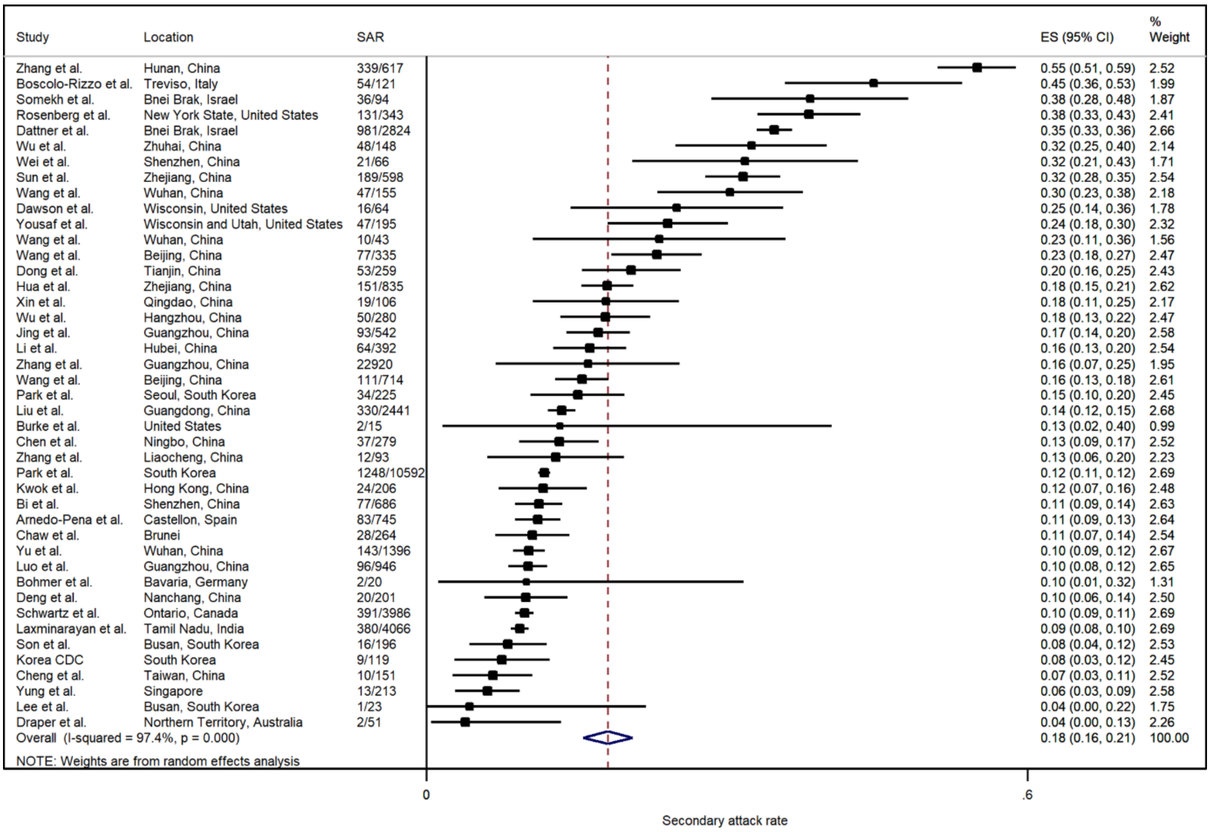
The secondary attack rates (SAR) associated with activities and settings

Two systematic reviews[20, 23] and three primary research studies[10, 17, 28] estimated the SARs associated with various activities and settings.

Evidence syntheses

Koh et al. conducted a systematic review and meta-analysis, with the aim of estimating the SAR of SARS-CoV-2 in household, healthcare and other settings.[20] The literature searches were conducted between 1 January and 25 July 2020. A total of 57 studies were included in the meta-analysis, with only academic publications included. A total of 43 clusters were identified in household settings, 18 in healthcare settings and 17 in a broad range of other settings. The authors estimated a pooled household SAR of 18.1% (95% CI, 15.7%-20.6%), although there was considerable heterogeneity (I^2=97.4%) with the SAR ranging between 4% and 55% across studies (Figure 2). Based on three studies with available data, the household SAR was significantly higher for symptomatic index cases (relative risk (RR) of 3.23 (95% CI, 1.46-7.14)) than for asymptomatic and pre-symptomatic cases. This difference may be explained by the fact that transmission may have already occurred by the time a case first experiences symptoms.[31] With respect to age, the SAR results from 14 studies showed that close contacts who were adults were more likely to be infected than children (< 18 years old), with a relative risk of 1.71 (95% CI, 1.35-2.17); however, there was substantial heterogeneity among the included studies (I^2=69%). In seven studies, spouse relationship to index case was associated with a significantly higher risk of infection (RR, 2.39; 95% CI, 1.79-3.19) when compared with other household members, though this finding was also subject to substantial heterogeneity among the included studies (I^2=68%).[20]

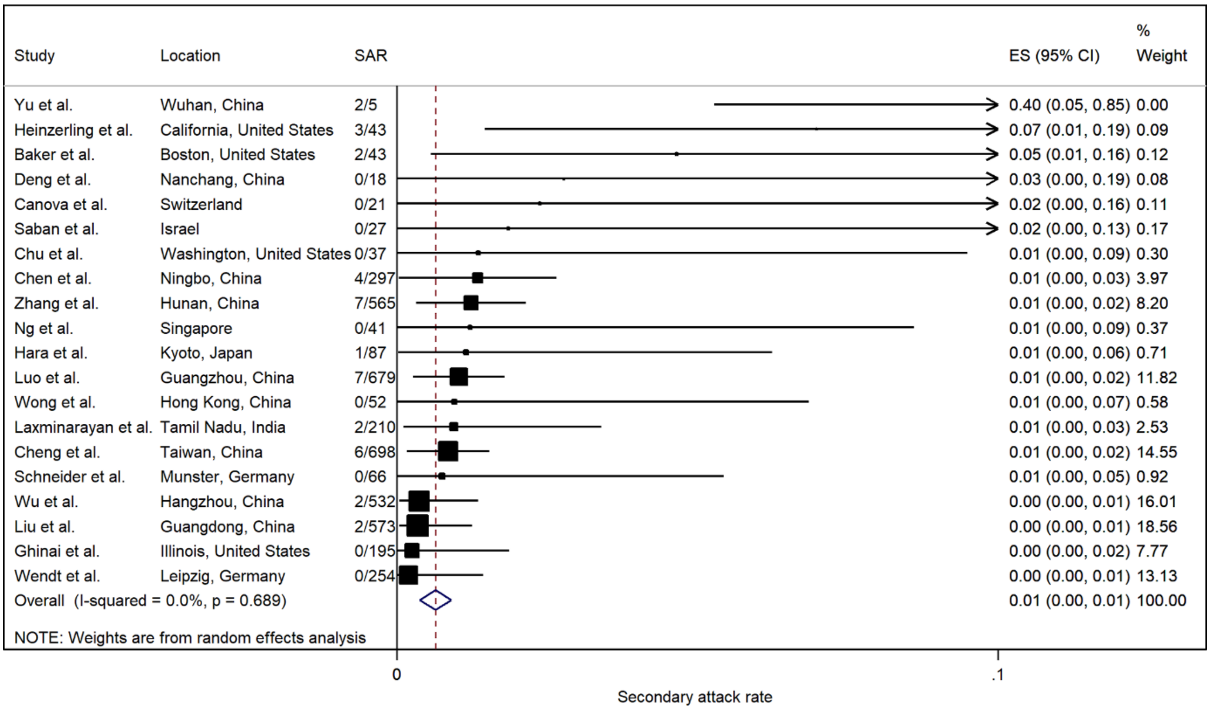
Figure 2. Forest plot of household SAR.



Key: CDC – Centre for Disease Control and Prevention; ES – Estimated secondary attack rate; SAR- secondary attack rate.
Source: image reproduced directly from Koh et al.[20]

In contrast, the pooled healthcare SAR was estimated to be 0.7% (95% CI, 0.4%-1.0%), with no heterogeneity (I^2=0%) (Figure 3). The SAR in healthcare settings in most studies was generally low (< 2%), except for a single study in Wuhan that indicated that two of five (40%) healthcare personnel were infected. This substantially lower SAR in healthcare settings may be due to infection prevention and control measures being standard practice in these settings. The authors identified seventeen studies that allowed estimation of SAR in settings other than household or healthcare. However, given the diversity of these settings, a meta-analysis was not undertaken. Considering individual settings among these, high SARs were observed in a meeting (84.6%), a chalet (73.3%), and at choirs (70.4% and 53.3%) and relatively high SARs were reported in situations involving dining (38.8% and 28.6%), travelling together in close proximity of less than one metre (80.8%) and religious celebration (14.8%). SARs were much lower in encounters with relatives (3.5% to 6.6%), social contacts (0.9% to 2.2%), and at the workplace or school (0% to 5.3%).[20]

Figure 3. Forest plot of healthcare SAR.



Key: ES – Estimated secondary attack rate; SAR- secondary attack rate.
Source: image reproduced directly from Koh et al.[20]

Prakash undertook a meta-analysis of selected literature with the aim of estimating the risk of SARS-CoV-2 transmission between asymptomatic individuals who were known to each other and who were in the setting of 'every day' activities.[23] However, the dates of literature searching are unknown and the process for selecting the studies was not provided. Therefore, the findings from this review must be interpreted with caution. The authors report on 20 different clusters where 418 people became infected by 44 index cases. SARs due to workspace interactions were reported to range from 6.3% to 78.7%. The highest SAR was observed in an open work space with everyone talking and with no physical separation, while the lowest SAR was observed in a conference. SARs due to social events were reported to range from a 'low' undefined proportion to 86.9%. The highest SAR was observed in a singing group with extensive mixing, while the lowest SAR was observed in a close spaced gathering with limited mixing. SARs due to family events were reported to range from 15.7% to 66.7%. The highest SAR was observed at a family dinner, while the lowest SAR was observed at a sit-down dinner with limited mixing. Evidence of onward transmission due to transport was very limited. While a SAR of 100% was observed in a car journey, only one person was infected. No onward transmission was observed in an elevator and lobby area, or on a metro train; masks may have been used in these settings but this is not clearly reported.[23]

Primary research studies

As previously discussed, Ng et al. conducted a retrospective cohort study with a nested case-control element in Singapore, between 21 January and 3 April 2020.(28) The aim of the study was to determine the overall prevalence of SARS-CoV-2 infection and epidemiological risk factors among exposed individuals in Singapore. The study included 7,518 close contacts (1,779 household, 2,231 work, and 3,508 social contacts) of PCR confirmed cases, who had complete patient data. Based on symptom-based PCR testing alone, the SAR was estimated to be 5.9% (95% CI, 4.9-7.1%) among household contacts, 1.3% (95% CI, 0.9-1.9%) among work contacts and 1.3% (95% CI, 1.0-1.7%) among social contacts. The authors additionally performed serology testing (to test for antibodies to SARS-CoV-2) in those who consented, to capture asymptomatic cases who would have been missed by a symptom-based PCR testing strategy. Serology testing was conducted at least two weeks after close contacts completed their 14 day quarantine period. Bayesian modelling approaches were undertaken to adjust for differential serology testing rates between consenting and non-consenting contacts, and estimated that 62% of COVID-19 cases (95% credible interval, 55-69%) were missed by the symptom-based PCR testing strategy. Considering both symptom-based PCR testing and serology testing results (and adjusting for differential testing rates), the estimated SAR increased across all settings. Including all contacts who had either a positive PCR test or a positive serology test, the SAR was estimated to be 11 (95% credible interval, 9–14) per 100 household contacts, 5 (95% credible interval, 3–8) per 100 work contacts and 4 (95% credible interval, 3–5) per 100 social contacts.

Also, as discussed previously, Jia et al. conducted a retrospective cohort study in Fuzhou, China, investigating the risk of infection for close contacts of cases in different settings and situations between 22 January and 29 February 2020.(17) The overall SAR was 2.1% (24 infected from 1,159 close contacts). The SAR was highest in older people in care homes (28.6%), followed by family members (5.5%), medical staff (3.2%), relatives (2.4%), and colleagues and classmates (1.7%). No onward transmission to friends was observed in this study.(25)

Also, as discussed previously, Adam et al. conducted a retrospective cohort study in Hong Kong between 23 January and 28 April 2020, with the aim of estimating the potential for SSEs.(10) From the 169 unique infector-infectee transmission pairs identified in the study, transmission within family households occurred most frequently (n=92 of 169, 54.4%), followed by social settings (n=56 of 169, 33.1%) and work settings (n=20 of 169, 11.8%). However, following controlling for the age of individual infectors, the authors found that transmission in social settings was significantly associated with more secondary cases than households (p= 0.002), thereby indicating the significant potential for SSEs within social settings.

Methodological quality of included studies

There are important methodological limitations associated with all included studies. In terms of the evidence syntheses, all seven were judged to have inadequate search strategies, with the possibility that these reviews are missing relevant studies.(4, 14, 20-24) Furthermore, only one of the evidence syntheses undertook quality appraisal of included studies,(20) and only one evidence synthesis explicitly reported data extraction by two independent reviewers.(22) Other concerns include the limited number of databases screened,(14, 20, 23, 24) and insufficiently addressing publication bias.(22-24) As these evidence syntheses were largely rapid reviews conducted to facilitate faster decision-making, it is generally accepted that certain steps of the traditional systematic review process (that is, searching, screening, quality appraisal, data extraction and or analysis) may be streamlined or removed altogether.(32) However, it is important to acknowledge that use of these rapid processes may increase the risk of missing or misinterpreting important studies.(33)

In relation to the primary research studies, which were all observational in design, there was a considerable risk of bias due to the lack of controlling for confounders,(13, 16-19, 25-27) or the incomplete matching of case and control participants.(15) Hence, the study findings may be biased, especially if unadjusted estimates were presented. Across all studies, it is also unclear whether patients were necessarily free of the outcome (that is, infection with SARS-CoV-2) prior to exposure to specific settings; factors contributing to this uncertainty include the prolonged and variable incubation period associated with COVID-19,(34) and the sizeable proportion of asymptomatic cases.(35) There was also uncertainty in some studies as to whether follow-up was sufficiently long enough for the outcome (that is, infection) to be measured, particularly if testing of contacts was symptom-based.(13, 16, 25, 29)

Finally, five of the studies (three evidence syntheses and two primary research studies) included in this review are published as pre-prints, so have not yet been formally peer-reviewed, raising additional concerns about overall quality and the potential for results to change prior to formal publication.(17, 19, 21, 23, 24)

Discussion

Main findings

There is consistent evidence that SARS-CoV-2 clusters predominate in household settings,(4, 17, 21, 22, 26) and that the secondary attack rate (SAR) is higher in these settings relative to other settings.(20, 28) Other activities or settings where large numbers of clusters have been consistently observed include nursing homes, hospitals, meat and food processing plants, large shared accommodation, sporting activities, bars, nightclubs and restaurants, gyms, offices, shopping malls, and religious settings.[4, 10, 13-19, 21-23, 25, 27, 29] Activities involving dining, drinking, exercising, singing or shouting, prolonged face-to-face conversation, particularly in indoor, crowded environments, appear to be associated with an increased risk of transmission in several studies.[4, 10, 15, 16, 21, 22, 25, 26, 28] Certain settings or activities have been associated with SSEs, whereby a larger number of individuals than is usual has been infected by a single cluster.[8] These include health and social care settings, meat and food processing plants, cruise ships, prisons, shopping malls, religious settings, bars, nightclubs and restaurants, festivals, gyms, offices, weddings, large shared accommodation, and mines.[4, 10, 14, 16-19, 21-23, 26, 27, 29] The main factors found to contribute to transmission risk include: indoor environments, crowds, and prolonged and intense contact with others.[21, 28] The evidence base included in this evidence summary is observational in nature and considers settings and activities that contributed to increased SARS-CoV-2 transmission. While not investigated as part of the included literature, the implementation of effective infection prevention and control measures may mitigate some of the transmission risk associated with these settings and activities.

While there is consistent evidence that the risk of outdoor transmission of SARS-CoV-2 is substantially lower,[4, 21, 24] there is still evidence of transmission occurring in outdoor environments, particularly when there are large gatherings, where social distancing and or use of face coverings are neglected, and or there is dense congregation and mixing among groups.[24, 27] For example, recent political campaign rallies in the US, which mostly occurred outdoors, may have served as SSEs and potentially resulted in more than 30,000 cases and more than 700 deaths.[36] Additional factors associated with attending outdoor events that may contribute to the spread of the virus include communal travelling, indoor congregation in bars and cafes, or collective stays in overnight accommodation.[24, 27] The substantially lower risk of transmission in outdoor settings points to the importance of adequate ventilation as a means of mitigating risk. The ECDC have concluded that well-maintained heating, ventilation and air-conditioning (HVAC) systems that are adapted for use in the COVID-19 pandemic "may have a complementary role in decreasing potential airborne transmission of SARS-CoV-2."[37] The ECDC recommend that in the context of reducing the transmission risk within closed spaces, four bundles of non-pharmaceutical interventions should be considered:[37]

1. The control of COVID-19 sources in closed spaces (that is, preventing COVID-19 positive cases, people with COVID-19-related symptoms and close contacts of positive cases, from meeting with other people in closed spaces).

2. Engineering controls in mechanically ventilated and naturally ventilated closed spaces (that is, ensuring HVAC systems are maintained to a high standard,

increasing the air exchange rate, avoiding the use of air recirculation, and opening doors and windows, where possible).

3. Administrative controls (that is, limiting the number of people and the maximum duration of stay, in closed spaces).

4. Personal protective behaviour (that is, implementing physical distancing, hand hygiene, respiratory etiquette, and face coverings in closed spaces).

IPC measures that include a focus on adequate ventilation and improved air turnover, may mitigate against a potential increased risk of transmission in settings where longer duration activities and higher densities cannot be avoided.

Comparison with extant literature

The predominance of clusters within indoor, congregated settings, where social distancing and wearing of face coverings may not be possible, is in keeping with the current understanding of how SARS-CoV-2 is transmitted. The World Health Organization (WHO) states that "transmission of SARS-CoV-2 occurs primarily between people through direct, indirect, or close contact with infected people through infected secretions such as saliva and respiratory secretions, or through their respiratory droplets, which are expelled when an infected person coughs, sneezes, talks, or sings."[38] There is also emerging evidence for the role of airborne transmission via aerosols, which may explain SSEs in settings such as meat and food processing factories.[39] However, a previous review by HIQA highlighted there is uncertainty as to the nature and impact of aerosol transmission of SARS-CoV-2, and its relative contribution to the COVID-19 pandemic compared with other routes of transmission.[40]

The pattern of SARS-CoV-2 clusters in included studies is broadly in line with what has been observed in the Irish setting. Up until 24 October 2020, a total of 6,228 SARS-CoV-2 clusters were notified to the Health Protection Surveillance Centre (HPSC).[41] Of the 6,228 clusters, the majority were associated with private houses (n=4,498, 72.2%). The next largest cluster setting was nursing homes (n=328, 5.3%), followed by residential institutions (n=243, 3.9%), hospitals (n=140, 2.2%) and schools (n=126, 2%). In relation to school clusters, the HPSC note that transmission of SARS-CoV-2 within the school itself has not necessarily been demonstrated in all clusters, and test positivity rates remain low in this setting (2.9% as of 28 October).[41, 42] Retrospective contact tracing, whereby the source of infection of each case is identified, is currently not routinely undertaken in Ireland, however a pilot project is planned.

The Scientific Advisory Group for Emergencies (SAGE) who provide scientific and technical advice to the UK government, published a report on SARS-CoV-2 transmission routes and environments on 22 October 2020.[43] SAGE concluded, with high confidence, that transmission of SARS-CoV-2 is strongly associated with proximity and duration of contact in indoor environments. SAGE also concluded, with high confidence, that the highest risks of transmission are associated with poorly ventilated and crowded indoor settings with increased likelihood of aerosol emission (such as loud singing or speech, aerobic activity) and where no face coverings are worn such as bars, nightclubs, parties or family gatherings, indoor dining, gyms and exercise classes, choirs and churches. The critical importance of targeting settings conducive to SSEs to control the spread of SARS-CoV-2 is also highlighted by SAGE with high confidence. SAGE also reported with medium confidence, that within the same household, frequent prolonged daily contact with the index case, such as dining in close proximity or sleeping in the same room, is associated with increased transmission. The findings from the current report are in strong agreement with that of SAGE.

An evidence summary conducted by the Public Health Agency of Canada (PHAC), concluded that SSEs were associated with large gatherings, an asymptomatic or mildly symptomatic index case, indoor environments, and close and sustained contact, and often involved loud talking, shouting and singing.[44] The viral load of the index case also likely affects transmission.[44, 45] The findings from the current evidence summary are in agreement with that of the PHAC, and point to the critical importance of applying public health measures in these high risk settings, and curtailing activity in those at the highest level of risk (such as nightclubs), particularly when levels of community transmission are high.[18] Jones et al. have recently developed a graded assessment tool to estimate the risk of SARS-CoV-2 transmission based on factors such as occupancy, ventilation, speaking volume, nature of contact, and the use of face coverings.[46] The authors suggest that the highest risk of transmission is presented by indoor, high occupancy, poorly ventilated environments, where there is shouting and singing, lack of face coverings, and prolonged contact.[46] Given the potentially overdispersed nature of SARS-CoV-2 transmission (that is, relatively few individuals infect the majority of cases),[10] it has been argued that "broad and untargeted interventions may be less effective than expected, whereas interventions targeted at settings conducive to superspreading (such as mass gatherings and hospitals) may have an outsized effect."[47] Focusing restrictive measures towards those settings at the highest level of risk, while allowing lower risk activities to continue, may be an effective means of balancing public health risk with economic recovery and broader societal needs. This approach is broadly in line with the framework adopted in the Irish Government's Plan for Living with COVID-19.[48]

An important finding of this evidence summary was the high SAR in household settings, highlighting that households are a driver of SARS-CoV-2 transmission due to the high frequency and intensity of contacts that occur between family members.(20) Koh et al. reported that the estimated household SAR for SARS-CoV-2 (18.1%) was higher than the upper range of estimates of the household SAR for the 2009 H1N1 pandemic influenza (5–15%), and also higher than that observed for both SARS (5–10%) and MERS (4–5%).(20) For seasonal influenza, the household SAR ranges from 5% to 40%, depending on the influenza subtype and how SAR is measured, making direct comparisons difficult.(49) These findings suggest higher levels of transmissibility of SARS-CoV-2 in household settings compared with SARS, MERS and the 2009 H1N1 pandemic influenza, however the relative transmissibility of SARS-CoV-2 in household settings compared with seasonal influenza remains unclear. The high household SAR for SARS-CoV-2 underpins the rationale for instructing advising infected individuals, including those awaiting test results and those with symptoms indicative of COVID-19 to adhere to self-isolation guidelines. Self-isolation means staying indoors, in a room with a window that can open, and completely avoiding contact with other people, including, where possible, household members. It is also recommended to use a different bathroom to others in the household and to clean the room every day with disinfectant.(50) Given the significant transmission risk associated with household settings, some of the included studies advise isolating infectious cases in a separate location, away from other household members, as soon as possible to minimise onward transmission.(20, 21) To this end, the Health Service Executive (HSE) provides a self-isolation facility for people who cannot safely self-isolate at home; admission occurs following a referral from an individual's GP, hospital, or contact tracing team.(51) However, irrespective of the provision of an appropriate facility, there may be additional barriers where an individual has personal responsibilities (for example, caring for a child) or requirements (for example, medical conditions), that preclude effective self-isolation.

A UK survey (n=42,127 responses) found that of those who reported experiencing symptoms of COVID-19, only 18.2% (95% CI, 16.4%-19.9%) self-reported fully adhering to COVID-19 self-isolation guidelines. However, 70% of respondents reported that they intended to self-isolate if they were to develop symptoms. The factors most strongly associated with non-adherence to self-isolation were: not knowing government guidance; not identifying COVID-19 symptoms; thinking they were previously infected with COVID-19; having a dependent child in the household; and working in a key sector. Self-reported reasons for not self-isolating included: shopping for groceries/visit pharmacy (18.2%); symptom resolution (15.6%); and non-COVID-19 medical needs (14.9%).(52) These are important barriers that need to be addressed in order to improve compliance with self-isolation guidelines.

Just as in households, those who live in congregated residences, such as, worker dormitories, prisons, and long-term care facilities, have intense, long-duration, close contact. There are more potential contacts in these settings, and in the case of long term care facilities, are often among older age groups and or among those with underlying medical conditions. This may contribute to high infection rates in these settings.[47] Clusters in nursing home settings in particular, can result in significant rates of mortality among residents;[53] as such, stringent infection prevention and control measures are necessary to protect the most vulnerable in society.[53, 54] Workers who live in shared, crowded accommodation may not be able to safely self-isolate, and may not be able to afford time off work; large outbreaks have been observed in these settings.[55]

Strengths and limitations

This evidence summary is undertaken based on information and data available at the time of writing. A number of limitations need to be considered when interpreting its findings. Reporting bias is a particular problem with regards to synthesising data on SARS-CoV-2 clusters. Given that there are currently over 44 million cases of COVID-19 globally (as of 28 October),[1] the clusters reported in this evidence summary (causing at most, approximately 70,000 cases) represent a very small proportion of all clusters to date. It is not clear whether the pattern of clusters documented in the included reports is reflective of the general pattern of clusters, or whether they are systematically different.

Recall bias is another important consideration with regards to the investigation and reporting of SARS-CoV-2 clusters. For example, social events, such as weddings and concerts, may be more likely to be recalled than everyday activities, such as grocery shopping or working, so transmission may be attributed to these social events when they may not necessarily be the source of infection.[4, 44]

Another consideration with regards to interpreting data on clusters is that the level of protective behaviours adopted by individuals (such as hand washing and physical distancing), along with the level of restrictive measures that were in place at the time of reporting may have affected results. When lockdown measures were initially introduced, the number of settings in which transmission could occur were limited and were predominantly restricted to household, health and social care, or essential work settings.[20] Additionally, individuals reported engaging with protective public health measures such as staying at home, physical distancing and hand washing more than usual, during the initial stages of the pandemic.[56] However, as these restrictive measures eased, and many individuals' level of activity reverted to pre-pandemic norms,[57] during the spring and summer of 2020, clusters occurred in new settings (for example, nightclubs in South Korea).[18] There have reports of clusters in schools and universities across the world when these settings re-opened.[58, 59]

While several of the included evidence syntheses reported on the low frequency of clusters in educational settings,[4, 14, 21] this may have been influenced by the fact that these settings were largely closed at the time of reporting.[60] On re-opening educational settings, most countries have reported introduction of a wide range of IPC measures to mitigate risk, including use of face coverings for older students, increased emphasis and education on respiratory etiquette, hand hygiene and environmental cleaning.[61] Although transmission from child-to-adult or child-to-child in household and educational settings has been reported, transmission rates for younger children in particular, appear to be lower than for adults.[62]

The availability of testing also likely influenced results, as during the early pandemic phase, testing was largely restricted to healthcare workers and those who were symptomatic, due to limited capacity.[63] In this context, clusters involving mild or asymptomatic cases may not have been detected. Due to the expanded access to testing, a substantially larger number of COVID-19 cases are now being diagnosed, and so clusters in a wider range of settings are now likely to be identified. As time progresses, a different picture of where clusters occur may emerge.

Three of the seven evidence syntheses included in this evidence summary included media reports in order to gain additional, real-time, information on clusters that may not necessarily have been reported in academic publications.[4, 14, 21] One of these evidence syntheses acknowledged the biases caused by this approach, and stated that "a cluster is more likely to be reported [by the media] if controversial or if there is an interesting social narrative. This is then compounded by the method search engines use to provide results where priority is given to high traffic stories. Overall, this can lead to some settings being overly represented… which is why the numbers of clusters per settings should be compared cautiously." Additionally, media reports may contain inaccuracies, and are not formally peer-reviewed.[4] The authors further state that "other events, such as large music concerts, political and sporting gatherings, could potentially have been linked to clusters of COVID-19. But, in the absence of rigorous surveillance systems and widespread testing… such connections remain speculation."[4] While it is likely that these types of mass gatherings which occurred early in the pandemic may have been SSEs, it is difficult to prove, so these potential clusters are likely under-represented in the studies.

Under-reporting and over-reporting of clusters in particular settings is an issue also raised in the ECDC report, which examined clusters in occupational settings.[14] The authors of this report state that for certain settings, such as smaller businesses, reporting of clusters may be less likely, as this may impact negatively on their business.[14] There has also been a limited number of clusters observed in certain settings where high levels of transmission may have otherwise been expected. One such setting are airplanes, given the close contact between passengers and the often prolonged duration of travel.[64, 65] Only two clusters associated with airplanes were observed in total in this evidence summary (Table 2).[21] However, the absence of large numbers of published in-flight transmissions of SARS-CoV-2 is not evidence of safety. It is currently unclear whether these low numbers of observed clusters are the result of factors such as under-reporting or ongoing reduced passenger numbers contributing to lower overall risk or if they are indicative of a true low risk setting.[64]

Another important factor to consider is that many public health surveillance systems were quickly overwhelmed, particularly earlier on in the pandemic (and this is now occurring again as cases resurge), so they may not have been able to fully investigate sources of infection and chains of transmission, leading to significant under-reporting of clusters.[4] Conversely, due to serial testing in certain settings such as long-term care facilities and meat and food processing factories, clusters occurring in these settings may be over-represented in studies.[14] These points reinforce the argument not to interpret the findings from syntheses of SARS-CoV-2 clusters as absolute, but rather as initial estimates and hypothesis-generating results. Ongoing, robust surveillance and contact tracing (including retrospective contact tracing or source finding) across settings is critical to identify how, where, and when clusters occur and to inform the most appropriate policy measures to control the spread of SARS-CoV-2, especially given the potential for overdispersion with this virus.[66]

Conclusion

The transmission pattern of SARS-CoV-2 appears to be highly overdispersed with a small proportion of cases potentially causing the majority of local transmission. Indoor, high occupancy, poorly ventilated environments, where there is shouting and singing, insufficient use of face coverings, and prolonged contact, present the highest risk of SARS-CoV-2 transmission. However, the implementation of effective infection prevention and control measures may mitigate some of the transmission risk associated with these settings and activities. SARS-CoV-2 clusters predominate in household settings, and household members are at a high risk of infection when a positive case is present. While transmission is substantially lower in outdoor settings, characteristics associated with clusters of cases include large gatherings, limited social distancing, dense congregation, and mixing among groups.

To mitigate the additional risk of transmission, targeted public health measures are required in settings conducive to superspreading. The importance of adhering to self-isolation guidelines within households should be clearly communicated given the high risk of onward transmission in this setting.

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Appendix 1. Summary of included evidence syntheses

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:
ECDC

DOI:
https://www.ecdc.europa.eu/en/publications-data/covid-19-clusters-and-outbreaks-occupational-settings-eueea-and-uk

Study design:
Technical report (based on information from survey data, epidemic intelligence activities and a rapid literature review).

Date of searches:
Literature searches conducted up until 20 July 2020.
Survey disseminated on 5 July and completed by 24 July 2020.
Epidemic intelligence activities conducted between 1 May 2020 and 23 July 2020.</td>
<td>Research question/aim:

To detail the occurrence of COVID-19 clusters in different occupational settings in the EU/EEA and the UK, and the associated factors.

Number of included studies:

Unclear number of studies included.

Supplemented with data from health authorities in 17 countries who completed a de novo survey, and national and media reports (epidemic intelligence activities).

Setting or activity:

Occupational settings only.

Population:

A total of 1,376 clusters in occupational settings were</td>
<td>Main findings of report:

A total of 1,376 clusters in occupational settings were reported, including 18,170 COVID-19 cases and 166 deaths (from n=16 reporting countries in the EU/EEA/UK).

Number of cases per cluster:

Minimum: 2 (multiple settings)

Maximum: 704 (mining)

Average: 13.2

Table adapted from ECDC report (Data may relate to workers only, or else workers and patients/service users/clients/students) from n=16 reporting countries in the EU/EEA/UK.

<table>
<tr><th colspan="2">Setting</th><th>Number of clusters reported</th><th>Total number of cases reported</th><th>Number of reported deaths</th><th>Number of cases within a cluster (min-max)[1]</th></tr>
<tr><td rowspan="3">Health and social care</td><td>Hospitals</td><td>241</td><td>3,298</td><td>82</td><td>2-571</td></tr>
<tr><td>Long-term care facilities</td><td>591</td><td>5,670</td><td>46</td><td>2-342</td></tr>
<tr><td>Primary care facilities</td><td>4</td><td>14</td><td>0</td><td>2-5</td></tr>
</table>
</td>
<td>Factors associated with increased risk of transmission in occupational settings:

▪ indoors
▪ poor ventilation
▪ lack of physical distance
▪ shouting (due to noisy environment)
▪ prolonged duration of contact (work shifts)
▪ congregation in canteen, during breaks, changing rooms, clocking in/out
▪ face-to-face contact with infected patients
▪ lack of access to hand-washing facilities
▪ inadequate /inappropriate use of PPE</td>
</tr>
</table>

reported, including 18,170 COVID-19 cases and 166 deaths (from n=16 reporting countries in the EU/EEA/UK).

Food packaging and processing	**153**	**3,856**	**4**	**2-117**
Factory/manufacturing	**77**	**1,032**	**0**	**2-96**
Building and construction sites	**27**	**402**	**0**	**2-69**
Office	**65**	**410**	**4**	**2-23**
Educational facilities	**22**	**143**	**1**	**2-35**
Sales and retail	**22**	**188**	**6**	**2-30**
Military and law enforcement	**29**	**269**	**0**	**2-50**
Mines	**4**	**1,538**	**1**	**4-704**
Other occupational settings[2]	**79**	**696**	**4**	**3-35**
Unclassified	**63**	**682**	**18**	**2-52**
Total	**1 376**	**18,170**	**166**	**2-704**

[1]Excludes aggregated data reported by three countries.
[2]Includes various settings such as packaging/mail distribution, transportation, bars and restaurants, churches and monasteries, fitness clubs and spas.
Where location of occupational setting was available (n=447), 427 (95.5%) of these clusters occurred in settings that were described to be fully or predominantly indoor, while 20 (4.5%) clusters were reported in predominantly or fully outdoor occupational settings.

- exposure to multiple clients (e.g. transport workers, sales people, cleaners)
- shared, crowded accommodation
- shared transportation
- exposure to fomites (e.g. tools, surfaces)
- working despite symptoms, particularly for self-employed workers (e.g. 'presenteeism')
- lower socio-economic, ethnic minorities and those with migrant status (with reduced access to healthcare).

Study descriptors	Study characteristics	Primary outcome	Other relevant findings
Author/organisation: Lakha et al. **DOI:** https://superspreadingdatabase.github.io/Evidence_on_clusters_final.pdf **Study design:** Rapid review (pre-print). **Date of searches:** Searches were conducted between 1 December and 14 June 2020.	**Research question/aim:** To identify settings linked to SARS-CoV-2 clusters. **Number of included studies:** 96 studies plus 88 media reports (some overlap with Leclerc et al). **Setting or activity under investigation:** Any setting.	**Documented settings associated with SARS-CoV-2 transmission clusters, correct as of 14 June 2020 (adapted from Lakha et al)**	Several key factors which can increase transmission risk: ▪ Indoor environments pose a greater risk than open-air spaces; ▪ Crowded environments, and spaces in which people have more prolonged and/or intense contacts in close proximity with each other. Large clusters have occurred in settings where large numbers of people congregate or reside, such as large group accommodation, confined working environments with large numbers of employees, and mass gatherings. The majority of documented clusters have been associated with household transmission,

Setting type	Setting detail	No. reported clusters n=616	% total reported clusters	Total cluster size			Total no. of cases n=20,471	% total reported cases
				Min	Median	Max		
Household (n=306, 50%)		306	50%	2	3	8	1,115	5.4%
Entertainment and leisure (n=94, 15%)	Dining	58	9%	2	18	47	1,097	5.4%
	Sports – gym, fitness, table tennis, running	19	3%	2	4	92	179	0.9%
	Party	6	1%	7	18	60	179	0.9%
	Music venue, nightclub, indoor carnival	6	1%	3	20	20	100	0.5%
	Bar	5	1%	4	10	77	112	0.5%
Large group living (n=63, 11%)	Worker dorms, shelters, refugee housing,	26	4%	3	43	797	2,286	11.2%
	Elderly care home	23	4%	5	27	167	906	4.4%
	Cruise liner, Navy Ship	5	1%	78	662	1,156	3,597	17.6%
	Hotel	4	1%	3	8	13	24	0.1%
	Prison	5	1%	66	225	353	989	4.8%

Workplace (n=54, 9.5%)	Office/meeting	29	5%	4	6	30	258	1.3%
	Processing plant/ slaughterhouse/ factory	12	2%	3	76	534	1,843	9%
	Conference	5	1%	3	10	89	148	0.7%
	Shipyard/construction site	5	1%	5	22	49	117	0.6%
	Call centre/Mail centre	3	0.5%	8	97	164	269	1.3%
Public spaces (n=40, 6.2%)	Shopping/ supermarket	32	5%	7	13	87	588	2.9%
	Outdoor market	3	0.5%	25	27	163	215	1.1%
	Community centre	3	0.5%	10	10	10	30	0.1%
	Playground	2	0.2%	20	23	26	46	0.2%
Religious (n=22, 3.5%)	Religious services	19	3%	2	29	4,482	5,,,136	25.1%
	Choir practice	3	0.5%	53	59	102	214	1%
Health care facility (n=14, 2%)		14	2%	2	10	118	325	1.6%
Educational setting (n=10, 2%)		10	2%	2	15	133	368	1.8%
Travel related (n=8, 1%)		8	1%	2	8	30	89	0.4%
Other social gatherings (n=5, 0.9%)	Funeral	1	0.2%	4	4	4	4	<0.1%
	Wedding	3	0.5%	13	43	98	154	0.8%
	Rally	1	0.2%	83	83	83	83	0.4%

highlighting the importance of isolation of cases from their household members, wherever possible, and rapid quarantine of their household members and other close contacts.

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:
Leclerc et al.

DOI:
10.12688/wellcomeopenres.15889.2

Study design:
Systematic review (combined with a publicly available online database, where individuals can suggest clusters for inclusion) https://bit.ly/3ar39ky (peer reviewed).

Date of searches:
Literature searches conducted, using PubMed, between 1 December 2019 and 30 March 2020.
Media articles searched, using Google, on the week beginning 6 April 2020.
Suggested updates from individuals, using the</td>
<td>Research question/aim:

To gather information on reported clusters of COVID-19 cases to determine types of settings in which SARS-CoV-2 transmission occurred.

Number of included studies:

Unclear number of studies (also includes media reports).

Setting or activity under investigation:

Any setting. (Restricted to the first-generation of cases that acquired the infection due to transmission in a single specific setting at a specific time).</td>
<td>Location of reported clusters as of 6 July 2020 (Table extracted from Leclerc et al. online database https://bit.ly/3ar39ky)
<table>
<tr><th>Setting</th><th>Number of clusters per setting (% of total)</th><th>Total number of cases per cluster (% of total)</th><th>Median cases per cluster</th></tr>
<tr><td>Building site</td><td>4 (1.5%)</td><td>95 (0.6%)</td><td>20.5</td></tr>
<tr><td>Conference</td><td>5 (1.9%)</td><td>148 (0.9%)</td><td>10</td></tr>
<tr><td>Elderly care</td><td>21 (7.9%)</td><td>820 (5.2%)</td><td>27</td></tr>
<tr><td>Food processing plant</td><td>21 (7.9%)</td><td>3,958 (25.3%)</td><td>70</td></tr>
<tr><td>Funeral</td><td>2 (0.8%)</td><td>27 (0.2%)</td><td>13.5</td></tr>
<tr><td>Hospital</td><td>9 (3.4%)</td><td>224 (1.4%)</td><td>10</td></tr>
<tr><td>Hotel</td><td>3 (1.1%)</td><td>23 (0.1%)</td><td>7</td></tr>
<tr><td>Household</td><td>38 (14.3%)</td><td>178 (1.1%)</td><td>4</td></tr>
<tr><td>Large shared accommodation</td><td>30 (11.3%)</td><td>2,493 (15.9%)</td><td>44.5</td></tr>
<tr><td>Meal (in any setting)</td><td>17 (6.4%)</td><td>134 (0.9%)</td><td>5</td></tr>
<tr><td>Party (including Bars, Clubs)</td><td>14 (5.3%)</td><td>422 (2.7%)</td><td>16.5</td></tr>
<tr><td>Prison</td><td>6 (2.3%)</td><td>1,049 (6.7%)</td><td>171.5</td></tr>
<tr><td>Public spaces (including parks and welfare centres)</td><td>6 (2.3%)</td><td>122 (0.8%)</td><td>15</td></tr>
<tr><td>Religious</td><td>22 (8.3%)</td><td>897 (5.7%)</td><td>23</td></tr>
<tr><td>School</td><td>11 (4.2%)</td><td>374 (2.4%)</td><td>16</td></tr>
<tr><td>Ship (including cruises)</td><td>5 (1.9%)</td><td>3,689 (23.6%)</td><td>712</td></tr>
<tr><td>Shipyard</td><td>1 (0.4%)</td><td>22 (0.1%)</td><td>22</td></tr>
<tr><td>Shopping</td><td>8 (3%)</td><td>333 (2.1%)</td><td>16.5</td></tr>
</table>
</td>
<td>The vast majority of clusters were associated with indoor or combined indoor/outdoor settings. Only the 4 building sites clusters (with 95 cases) were classified as purely outdoors.</td>
</tr>
</table>

online database, correct as of 6 July 2020.		Sport	22 (8.3%)	163 (1%)	5.5	
		Transport	1 (0.4%)	3 (<0.1%)	3	
		Wedding	4 (1.5%)	231 (1.5%)	60	
		Work	15 (5.7%)	235 (1.5%)	8	
		Total	**265**	**15,640**	**13**	

Study descriptors	Study characteristics	Primary outcome	Other relevant findings
Author/organisation: Koh et al. **DOI:** 10.1371/journal.pone.0240205 **Study design:** Systematic review and meta-analysis (peer-reviewed). **Date of searches:** Searches conducted between 1 January 2020 and 25 July 2020.	**Research question/aim:** To estimate the SAR in household, healthcare and other settings. **Number of included studies:** 57 studies included in meta-analysis (academic literature only). **Setting or activity under investigation:** Household, healthcare and other settings. **Population:** 43 clusters in households, 18 clusters in healthcare settings and 17 clusters in other settings.	**Pooled Household SAR (n=43 studies):** 18.1% (95% CI: 15.7%-20.6%). Heterogeneity: I^2=97.4% Range: 3.9% - 30% **Pooled Healthcare SAR (in staff and/or patients) (n=18 studies):** 0.7% (95% CI: 0.4%-1.0%). Heterogeneity: I^2=0% Range: 0% - 40% (but majority <2%). **SAR in other settings (not pooled) (n=17 studies):** These "other setting" studies were not pooled given differences in settings. Huge variation (0%-84.6%). High SARs were observed in a meeting (84.6%), a chalet (73.3%), and at choirs (70.4%, 53.3%). Relatively high SARs were reported in eating (38.8%, 28.6%) and traveling (80.8%, 46.6%) with a case, as well as a religious event (14.8%). SARs were much lower in encounters with relatives (3.5% to 6.6%),	Household SAR of symptomatic index cases were significantly higher than asymptomatic and pre-symptomatic cases, with a relative risk (RR) of 3.23 (95% CI: 1.46, 7.14). Close contacts who were adults were more likely to be infected compared to children (< 18 years old), with a RR of 1.71 (95% CI: 1.35, 2.17. The SAR to spouses (37.5%; 95% CI: 22.2%, 52.7%) was higher than to other household contacts (16.3%; 95% CI: 10.6%, 22.1%). Reflecting on the high SAR in households and high AR in numerous non-household settings, the authors suggest that several common environmental factors could potentially account for the rapid person-to-person transmission observed: closed environments, population density, and shared eating environments. The authors conclude that, where possible, confirmed cases should be isolated away from the household.

		social contacts (0.9% to 2.2%), and at workplace or school (0% to 5.3%).	

Study descriptors	Study characteristics	Primary outcome	Other relevant findings
Author/organisation: Liu et al. **DOI:** 10.1016/j.ijid.2020.07.073 **Study design:** Systematic review (peer-reviewed). **Date of searches:** Searches conducted between 1 January and 15 June 2020.	**Research question/aim:** To summarise the major types of SARS-CoV-2 cluster infections worldwide through a comprehensive systematic review. **Number of included studies:** 65 studies (academic literature only). **Setting or activity under investigation** Any setting. **Population:** 108 clusters.	**Occurrence of clusters by setting or circumstance (n=number of clusters reported, %):** ▪ Families/household (n=62, 57%) ▪ Community transmission (n=4, 4%) ▪ Nosocomial infections (n=3, 2%) ▪ Gatherings (n=15, 14%) ▪ Transportation (n=6, 6%) ▪ Shopping malls (n=3, 2%) ▪ Conferences (n=4, 4%) ▪ Tourists (n=6, 6%) ▪ Religious organisations (n=5, 5%) ▪ Other settings (coal mines, prisons, offices, nursing homes) (not quantified). **Number of cases per cluster:** Min:1 (transportation and nosocomial clusters) Max:112 (fitness class (classified as a gathering cluster)) Median:7 Average:12.15	Effective risk communication is essential when taking social restrictions to minimise people's gatherings (meals, religious gatherings, etc.) and journeys outside the home.

Study descriptors	Study characteristics	Primary outcome	Other relevant findings
Author/organisation: Prakash **DOI:** 10.1101/2020.05.22.20110726 **Study design:** Meta-analysis of selected literature (pre-print) **Date of searches:** Not reported	**Research question/aim** To estimate the risk of SARS-CoV-2 transmission during everyday activities, from familiar, asymptomatic individuals. **Number of included studies:** Unclear number of studies (academic literature only). **Setting or activity under investigation:** Any "every day activity" where transmission occurred between individuals who were known to each other. **Population:** 20 different clusters where 418 people became infected by 44 index cases.	**Population:** 20 different situations where 418 people became infected by 44 index cases. **The SARs as estimated by the author:** ▪ Workspace interactions: range 6.3%-78.7% (Highest in an open work space with everyone talking and no physical separation. Lowest in a conference). ▪ Social events: range 'low'- 86.9% (Highest in a singing group with extensive mixing. Lowest in a close spaced gathering with limited mixing). ▪ Family events: range: 15.7%-66.7% (Highest at a family dinner. Lowest at a sit-down dinner with limited mixing). ▪ Transportation: range: 0-100% (Highest in a car journey, but only 1 other person infected. No onward transmission in an elevator and lobby or metro, with possible mask usage).	N/A

Study descriptors	Study characteristics	Primary outcome	Other relevant findings
Author/organisation: Weed et al **DOI:** 10.1101/2020.09.04.20188417 **Study design:** Rapid scoping review (pre-print) **Date of searches:** Searches conducted up until 16 August 2020	**Research question/aim:** To seek, evaluate and analyse evidence of incidents of outdoor transmission of COVID-19. **Number of included studies:** 14 studies reporting incidents of outdoor transmission (academic literature and government reports only) **Setting or activity under investigation** Any outdoor setting or activity. **Population:** N/A	**Main findings of narrative synthesis:** The majority of the sources included in the review stated that transmission of COVID-19 outdoors is a lower risk than indoors. Across sources, there is limited evidence of transmission of COVID-19 in outdoor environments during the natural course of everyday life. Only 4 sources of evidence were found relating to outdoor mass gatherings, however evidence of transmission is uncertain and may be subject to significant confounding (Champions League football matches in Italy, England and Spain; Black Lives Matter protests in the US; Horse racing festival in England; music concert in Wales). However, there is some evidence to suggest that there is a higher risk of outdoor transmission in environments where the natural social distancing that takes place when 'milling around' in everyday life is breached, and gathering density, circulation and size is increased, particularly where this involves an extended duration. This could include aspects of outdoor concerts, festivals and some types of physical activity and sporting events. 5 included sources refer to a link between weather conditions and transmission, all of which associate lower temperatures with higher transmission. All sources suggest at least a partial role for a behavioural effect, in which lower temperatures encourage people to spend more time indoors.	Based on the review findings, the authors deduce that there are 3 main considerations when organising events and activities that generate outdoors gatherings of people: 1. Does the event or activity prompt other behaviours that might increase transmission? (e.g. communal travel, indoor congregation in bars and cafes or collective stays in overnight accommodation) 2. For each part of the event or activity; the density, size, circulation and duration need to be considered. 3. Is rapid contact tracing possible in the event of an outbreak?

Appendix 2. Summary of included primary research studies

Study descriptors	Study characteristics	Primary outcome	Restrictive measures	Other relevant findings
Author/organisation: Adam et al. **DOI:** 10.1038/s41591-020-1092-0 **Study design:** Retrospective cohort study (peer reviewed) **Country:** Hong Kong. **Date of data collection** 23 January 2020 - 28 April 2020.	**Research question/aim** : To estimate the potential for superspreading while quantifying associated risks using contact tracing data to characterize SARS-CoV-2 clusters. **Sample size:** 1,038 confirmed SARS-CoV-2 cases. **Setting or activity under investigation:** ▪ Social ▪ Family ▪ Work ▪ Local travel ▪ Wedding ▪ Temple ▪ Bar.	**Number of clusters and superspreading events:** 4-7 SSEs identified across 51 clusters (n = 309 cases) and estimated that 19% (95% confidence interval, 15-24%) of cases seeded 80% of all local transmission, while 69% of cases did not transmit to anyone. The median cluster size was 2 and the largest involved 106 cases. **Setting:** Transmission within family households occurred most frequently (92/169, 54.4%), followed by social (56/169, 33.1%) and work (20/169, 11.8%) settings. Bars: The largest cluster comprised 106 cases and was traced back to a collection of four bars across Hong Kong, but the original source could not be determined. This single outbreak accounted for 10.2% (106/1,038) of all cases in Hong Kong during the study period. This cluster comprised at least 1 SSE. Wedding: associated with a cluster of 22 cases, and linked to 2 SSEs. Temple: associated with a cluster of 19 cases, with 12 cases directly linked to a SSE. All remaining local and imported SARS-CoV-2 clusters in Hong Kong, including three additional SSEs (SSE #5–7). **SAR:** Transmission in social settings was associated with more secondary cases than households when controlling for age (p = 0.002).	**26 Jan:** Barring entry of all non-Hong Kong residents with travel history to Hubei Province in the past 2 weeks. **9 Feb:** 14 day mandatory quarantine for all arrivals from mainland China. **23 Feb:** Mandatory quarantine for all arrivals from South Korea. **01 Mar:** Mandatory quarantine for all arrivals from Iran. **15 Mar – 22 Mar:** Mandatory quarantine for all arrivals from Italy, Schengen region followed by mandatory quarantine for all arrivals. **22 Mar- 29 Mar:** Barring entry of all non-Hong Kong residents from all overseas countries/territories and ban on public gatherings > 4 people.	**Superspreading Events (SSE's):** Gatherings in social settings such as bars, restaurants, weddings and religious sites appear to be at increased risk of superspreading events. Transmission in social settings was significantly associated with an increased number of secondary cases compared to transmission observed in family households.

			29 Mar – 05 April: Closure of leisure venues and bars During this study period, there was constrained community transmission given the moderate levels of physical distancing practiced in Hong Kong, including school closures, some adults working at home, cancellation of mass gatherings, as well as improved hygiene and universal mask wearing, which exceeded 98% compliance from February onward.	

Study descriptors	Population characteristics	Primary outcome	Restrictive measures in place	Other relevant findings
Author/organisation: Brandl et al **DOI:** https://doi.org/10.1017/S0950268820002460 **Study design:** Retrospective cohort study (peer reviewed). **Country:** Tirschenreuth, Germany **Date of data collection** 18 February to 12 March 2020.	**Research question/aim** : To investigate potential exposures at the beginning of the outbreak in Tirschenreuth, Germany. **Sample size:** Up until the beginning of May 1122 cases were reported in the district. The exposures for the first 110 cases were examined in this study. **Setting or activity under investigation:** ▪ Large one-day beer event in Mitterteich ▪ Ski vacation in Austria or Italy ▪ Smaller local beer festival in Mittertrich ▪ Other festivals or gatherings.	**Contact setting:** Of the first 110 cases identified, the most frequently reported exposures included having been guests at the small local beer festival between 3 March and 7 March 2020 (n=14, 13%), skiing vacation in Austria or Italy in February or March (n=12, 11%), and the large, 1-day beer event in Mitterteich (n=10, 9%). 3 cases (2%) had been skiing and guests at the smaller beer festival; 1 (1%) had been skiing and went to the large 1-day beer event. 27 cases (25%) reported other possible exposures with large numbers such as attending birthday parties, funerals or religious services. For 38 (35%) cases, no known exposure could be determined.	A series of measures were implemented between 10 March and 18 March. 10 Mar 2020: events with more than 1000 participants were banned. 11 Mar 2020: Kindergartens and schools were closed in Mitterteich. 18 Mar 2020: a complete lockdown was implemented in Mitterteich, followed by a partial lockdown for the entire state of Bavaria on 21 March 2020.	Returning ski-travellers from Austria and Italy and early undetected community transmission likely initiated the outbreak which was then accelerated by Bavarian beer festivities.

Study descriptors	Population characteristics	Primary outcome	Restrictive measures in place	Other relevant findings
Author/organisation: Chen et al. **DOI:** 10.1016/j.ajic.2020.06.006 **Study design:** Retrospective cohort study (peer reviewed) **Country:** China (Tianjin) **Date of data collection** Deadline of data collection March 13, 2020	**Research question/aim** : To analyse the data of confirmed COVID-19 cases from Tianjiin (China) in order to determine potential infection sources. **Sample size:** Epidemiological data of 136 confirmed COVID-19 cases were collected from the dataset of COVID-19 in Tianjin. **Setting or activity under investigation:** Department store **Patient demographics:** Median age, 49 years (interquartile range 36-46 years) Male, 73 (54.7%) Female, 63 (46.3%)	**Contact setting:** Among the 136 confirmed COVID-19 cases, 48 (35.3%) cases were categorised as imported cases and their close contacts, which were the majority of early cases. A total of 43 (31.6%) cases were found an epidemiological link to the Baodi department store, and they were inferred to be a common-source outbreak. Additionally, 35 (25.7%) cases were considered as familial clusters of COVID-19 cases, and 10 (7.4%) cases were sporadic.	China have a four level emergency response. Level I, the highest designation reserved for major, urgent public health incidents that require supervision and national coordination from the central government. Level I was initiated for all parts of mainland China on 25 January. As of 21 February, provinces within China began to step down their emergency response levels based on the risk level of the area (low, medium, high risk areas). On 21 February, six Chinese provinces lowered their Emergency Response levels. Shanxi and Guangdong from Level I to Level II. Liaoning, Yunnan, Guizhou, and Gansu from Level I to Level III.[67]	Most cases did not take any basic protective measures (eg, using masks) against the virus during that period. Moreover, all these cases were on the same floor, and then local transmission in this store might occur between customers and saleswomen

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Restrictive measures</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:

Fisher et al.

DOI:

10.15585/mmwr.mm6936a5

Study design:

Case control (peer reviewed)

Country:

United States (Participating states include California, Colorado, Maryland, Massachusetts, Minnesota, North Carolina, Ohio, Tennessee, Utah, and Washington

Date of data collection:

01 July 2020 - 29 July 2020.</td>
<td>Research question/aim :

To investigate what exposures are associated with COVID-19 among symptomatic adults ≥18 years in 11 outpatient healthcare facilities.

Sample size:

314 included (154) case-patients (positive SARS-CoV-2 test results) and (160) control-participants (negative SARS CoV-2 test results).

Setting or activity under investigation

▪ Shopping
▪ Home, ≤10 persons
▪ Home, >10 persons
▪ Restaurant
▪ Office setting
▪ Salon
▪ Public transportation
▪ Bar/Coffee shop
▪ Gym
▪ Church/Religious gathering.</td>
<td>Risk of infection with SARS-CoV-2 per setting/activity, OR (95% CI)

Case and Control patients:

Case-patients were symptomatic adults (aged ≥18 years) with SARS-CoV-2 infection confirmed by reverse transcription-polymerase chain reaction (RT-PCR) testing.

Control-participants were symptomatic outpatient adults from the same health care facilities who had negative SARS-CoV-2 test results.

Main finding:

Case-patients were more likely to have reported dining at a restaurant (any area designated by the restaurant, including indoor, patio, and outdoor seating) in the 2 weeks preceding illness onset than were control-participants (adjusted odds ratio [aOR] = 2.4; 95% confidence interval [CI] = 1.5-3.8).

Restricting the analysis to participants without known close contact with a person with confirmed COVID-19, case-patients were more likely to report dining at a restaurant (aOR = 2.8, 95% CI = 1.9-4.3) or going to a bar/coffee shop (aOR = 3.9, 95% CI = 1.5-10.1) than were control-participants.

<table>
<tr><th></th><th>aOR</th><th>95% CI Lower</th><th>95%CI Upper</th></tr>
<tr><td>Shopping</td><td>1</td><td>0.5</td><td>2</td></tr>
<tr><td>Shopping*</td><td>0.9</td><td>0.3</td><td>2.4</td></tr>
</table></td>
<td>Restrictive measures:

Restrictive measures vary across states but broadly speaking restrictions were lifted allowing businesses, bar and indoor activities including dining and entertainment to reopen between the period of May-June. Cases of COVID-19 rose following the lifting of restrictive measures forcing some states to re-impose restrictions. In late July the following states: Washington, Tennessee, Ohio, Minnesota and Maryland made mask wearing mandatory.[68]</td>
<td>Adherence to restrictive measures:

Among 107 participants who reported dining at a restaurant and 21 participants who reported going to a bar/coffee shop, case-patients were less likely to report observing almost all patrons at the restaurant adhering to recommendations such as wearing a mask or social distancing (p = 0.03 and p = 0.01, respectively).</td>
</tr>
</table>

Patient demographics:

Case patients: Male, 75 (48.7%) Female, 79 (51.3%)

	Case	Control
Age group	n=154	n=160
18-29	44 (28.6)	39 (24.4)
30-44	46 (29.9)	62 (38.7)
45-59	46 (29.9)	35 (21.9)
≥ 60	18 (11.7)	24 (15)

Home,<10	1.1	0.7	1.6
Home,<10*	0.9	0.6	1.3
Restaurant	2.4	1.5	3.8
Restaurant*	2.8	1.9	4.3
Office	0.8	0.5	1.5
Office*	0.9	0.5	1.8
Salon	0.9	0.4	1.7
Salon*	0.8	0.3	1.9
Home>10	0.4	0.9	1.9
Home>10*	0.7	0.4	1.1
Gym	1.6	0.7	1.6
Gym*	1.6	0.5	5.5
Public Transport	0.8	0.3	2.4
Public Transport*	0.9	0.2	4
Bar/coffee	2.2	0.9	5.6
Bar/coffee*	3.9	1.5	7.1
Church	1.8	0.7	5
Church*	1.7	0.5	5.4

*subset with no close COVID-19 contact

Study descriptors	Study characteristics	Primary outcome	Restrictive measures in place	Other relevant findings
Author/organisation: Furuse et al. **DOI:** 10.3201/eid2609.202272 **Study design:** Retrospective cohort study (peer reviewed). **Country:** Japan. **Date of data collection:** 15 January 2020 – 04 April 2020.	**Research question/aim** : Analysed cases of COVID-19 to determine what settings were associated with clusters. **Sample size:** Analysed 3,184 cases of coronavirus disease in Japan and identified 61 case-clusters in healthcare and other care facilities, restaurants and bars, workplaces, and music events. **Setting or activity under investigation** ▪ Healthcare facility ▪ workplace ▪ ceremonial function ▪ care facility ▪ music-related event ▪ transportation ▪ restaurant/bar ▪ gym. **Patient demographics:**	**Number of clusters:** 22 case patients contributed to the incidence of clusters. 61 clusters identified, defined as ≥5 cases with primary exposure reported at a common event or venue. **Cluster setting:** ▪ Healthcare facilities, 18 (30%) ▪ Care facilities of other types (such as nursing homes and day care centres), 10 (16%) ▪ Restaurant or bars, 10 (16%) ▪ Workplaces, 8 (13%) ▪ Music related events (including live music concerts, chorus group rehearsals, and karaoke parties), 7 (11%) ▪ gymnasiums, 5 (8%) ▪ Ceremonial functions, 2 (3%) ▪ Transport-related incident in an airplane, 1 (2%). **Number of clusters associated with each setting** **Cluster category** — **No. of clusters** Healthcare facility — 18 Care Facility — 10 Other — 33 **Total** — 61	Restrictive measures were introduced in Japan on January 29th. The public was advised to avoid crowded areas, refrain from going out and businesses largely closed. All elementary, junior high and other schools across the country closed. Nursery schools and kindergartens open as usual. However, the enforcement of restrictions remains unclear.(67)	COVID-19 clusters were associated with heavy breathing in close proximity, such as singing at karaoke parties, Cheering at clubs, having conversations in bars, and exercising in gymnasiums. Among the probable primary COVID-19 cases identified from non-nosocomial clusters, half (11/22) were 20–39 years of age, which is younger than the age distribution of all COVID-19 cases in Japan.

<table>
<tr>
<td></td>
<td>22 case-patients contributed to the incidence of clusters. Demographic data show that 9 (41%) probable primary case-patients were female and 13 (59%) were male.

Age: The most frequently observed age groups among probable primary cases were 20–29 years (n = 6; 27%) and 30–39 years (n = 5, 23%).</td>
<td>
Number of cases per cluster and associated setting
<table>
<tr><th></th><th>No. of clusters with 5-10 cases</th></tr>
<tr><td>Healthcare</td><td>10</td></tr>
<tr><td>Care facility</td><td>6</td></tr>
<tr><td>Other</td><td>22</td></tr>
<tr><td>Total</td><td>38</td></tr>
</table>
<table>
<tr><th></th><th>No. of clusters with 11-20 cases</th></tr>
<tr><td>Healthcare</td><td>5</td></tr>
<tr><td>Care facility</td><td>2</td></tr>
<tr><td>Other</td><td>9</td></tr>
<tr><td>Total</td><td>16</td></tr>
</table>
<table>
<tr><th></th><th>No. of clusters with 21-31 cases</th></tr>
<tr><td>Healthcare</td><td>1</td></tr>
<tr><td>Care facility</td><td>0</td></tr>
<tr><td>Other</td><td>1</td></tr>
<tr><td>Total</td><td>2</td></tr>
</table>
<table>
<tr><th></th><th>No. of clusters with >31 cases</th></tr>
<tr><td>Healthcare</td><td>2</td></tr>
<tr><td>Care facility</td><td>2</td></tr>
<tr><td>Other</td><td>1</td></tr>
<tr><td>Total</td><td>5</td></tr>
</table>
</td>
<td></td>
<td></td>
</tr>
</table>

Study descriptors	Population characteristics	Primary outcome	Restrictive measures in place	Other relevant findings
Author/organisation: Kang et al. **DOI:** 10.3201/eid2610.202573 **Study design:** Retrospective cohort study (peer reviewed). **Country:** South Korea (Seoul). **Date of data collection** 30 April 2020 - 06 May 2020.	**Research question/aim** : To investigate the exposure and spread of COVID-19 associated with nightclubs in Itaewon, Seoul, South Korea. **Sample size:** 5,517 persons for screening; of those, 1,257 were actively monitored. An additional 57,536 persons who had spent >30 minutes in the vicinity of the nightclubs, as determined by their cell phone location data, were sent a series of text messages encouraging them to undergo testing. **Setting or activity under investigation:** Nightclubs.	**Number of cases and contacts:** 246 confirmed night club-associated cases had been reported; 96 (39%) of those were primary cases and 150 (61%) were secondary cases. Prevalence of positive results for COVID-19 in night club visitors was 0.19% (67/35,827); in their contacts, 0.88% (51/5,785); and in anonymously tested persons, 0.06% (1/1,627). **Secondary attack rates:** The estimated attack rate among nightclub visitors was 1.74% (96/5,517).	Nightclubs that had been closed as part of the social distancing policy but reopened on April 30, ahead of the April 30–May 5 Golden Week holiday. On May 6, several COVID-19 cases were confirmed among persons who had visited night-clubs. On May 9, the Seoul Metropolitan Government announced indefinite closure of all nightclubs in Seoul to control the source of the outbreak. Subsequently, several regions prohibited mass gatherings.	N/A

Study descriptors	Study characteristics	Primary outcome	Restrictive measures	Other relevant findings
Author/organisation: Jia et al. **DOI:** 10.21203/rs.3.rs29844/v1 **Study design:** Retrospective cohort study (pre-print). **Country:** Fuzhou (China). **Date of data collection** 22 January 2020 - 29 February 2020.	**Research question/aim** : To understand the risk of infection and morbidity due to different exposure modes between COVID-19 cases and their close contacts. **Sample size:** 73 COVID-19 patients (72 symptomatic and 1 asymptomatic) (including 44 imported cases and 29 local cases) and 1,159 close contacts. **Setting or activity under investigation** The relationship between case and close contact: ▪ nursing care ▪ family members ▪ medical staff ▪ relatives ▪ colleagues/classmates.	**Number of contacts:** A total of 1,159 (range: 1-166) close contacts were identified and traced. **Number of clusters and associated setting:** 13 cluster events, including 10 household transmission (76.9%), 2 collective workplace clusters (15.4%), 1 in a residential nursing care facility (7.7%). The 13 cluster events involved 45 (61.6%) patients and 1 asymptomatic case. **Secondary Infection Rates (SIR):** The overall secondary infection rate (SIR) was 2.07% (24/1,159). *Relationships:* ▪ old people under care (28.57%) ▪ family members (5.52%) ▪ medical staff (3.23%) ▪ relatives (2.41%) ▪ colleagues / classmates (1.67%) ▪ friends and others (0%). *Setting/activity:* ▪ old people's (nursing) home (28.57%) ▪ living together (5.26%) ▪ family gathering (2.82%) ▪ same building (1.77%)	Targeted prevention and control measures were taken to stem the outbreak. In some cities, grid management and neighbourhood watches were initiated to detect and isolate suspected cases and their close contacts as soon as possible. From January 20, Fuzhou Health Commission, in collaboration with Fuzhou Center for Disease Control and Prevention (CDC) has taken a series of powerful measures, especially early detection and early isolation.	N/A

	The setting or activity associated with transmission. ▪ living together ▪ family gathering ▪ residential nursing care facility ▪ same vehicle ▪ medical contact (therapy, nursing, in the same ▪ ward, at the same time in hospital surrounding) ▪ other contact (such as in same building, short talk).	▪ short talk (1.55%) ▪ nursing therapy (3.23%).		

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Restrictive measures</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:
Kim et al.
DOI:
10.1101/2020.05.07.20091769
Study design:
Retrospective cohort study (pre-print).
Country:
South Korea.
Date of data collection
20 January 2020 – 7 April 2020.</td>
<td>Research question/aim :
To investigate network characteristics of person-to-person transmission in different granularity: entire country and individual cluster infections.
Sample size:
3,127 cases (representing 1,611 transmissions).
Focused on 12 clusters that had at least 20 cases (involving 1,231 cases in total).
Setting or activity under investigation:
Any setting with a cluster of at least 20 cases.
Patient demographics:
Until week 4 male to female ratio was similar (53% male; 47% female). After week 4</td>
<td>Cluster characteristics as of 7 April 2020
<table>
<tr><th>Cluster</th><th>Cluster size (total, n=1,231)</th></tr>
<tr><td>Imported cases (n=575, 46.7%)</td><td>575</td></tr>
<tr><td>Religious gatherings (n=288, 23.4%)</td><td></td></tr>
<tr><td>Shincheonji Church</td><td>149</td></tr>
<tr><td>River of Grace Community Church</td><td>67</td></tr>
<tr><td>Onchun Church</td><td>43</td></tr>
<tr><td>Dongan Church</td><td>29</td></tr>
<tr><td>Nursing homes (n=76, 6.2%)</td><td></td></tr>
<tr><td>Gunpo-si Nursing Home</td><td>22</td></tr>
<tr><td>Cheongdo Daenam Hospital Psychiatric Ward</td><td>22</td></tr>
<tr><td>Bonghwa Pureun Nursing Home</td><td>32</td></tr>
<tr><td>Gym facilities (n=98, 8%)</td><td></td></tr>
</table></td>
<td>There was no general lockdown of businesses in South Korea with supermarkets and other retailers remaining open. Kindergartens, schools, universities, cinemas, gyms were closed soon after the outbreak with schools and universities having online classes.[69]</td>
<td>Clusters with the smallest path lengths (the amount of successive cases infected in the transmission chain) were all related to nursing homes.

Clusters with the most considerable path length were related to gym facilities and a church.</td>
</tr>
</table>

	South Korea reported more female cases than male ones. Throughout all observations, the largest age group was 25-49 year olds.	**Gym Facility in *Cheonan-si***	63		
		Cheonan/Asan-si	35		
		Others (n=194, 15.8%)			
		Guro-gu Customer Call Center	164		
		Ministry of Oceans and Fisheries	30		

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Restrictive measures</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:
Ng et al.
DOI:
10.1016/S1473-3099(20)30833-1
Study design:
Retrospective cohort study, with a nested case-control study (peer reviewed).
Country:
Singapore
Date of data collection:
23 January 2020 – 03 April 2020.</td>
<td>Research question/aim :
To determine the overall prevalence of SARS-CoV-2 infection and epidemiological risk factors among exposed individuals in Singapore.
Sample size:
Retrospective cohort study: 7,518 close contacts (1,779 household, 2,231 work, and 3,508 social close contacts) of PCR confirmed cases, who had complete data. Household contacts were defined as individuals who shared a residence with the index COVID-19 case. Non-household close contacts were defined as those who had contact for at least 30 min within 2 m of the index case.
Case-control study: 1,248 close contacts (584 household contacts and 664 non-household contacts). Cases included both PCR-confirmed cases and individuals with a positive SARS-CoV-2 serology result. Controls were defined as individuals who completed quarantine without a COVID-19 diagnosis and had a negative serology test.
Settings under investigation
▪ household
▪ work
▪ social.</td>
<td>Secondary attack rates (SAR, 95% CI), based on symptom-based PCR testing:
▪ household, 5.9% (4.9–7.1%)
▪ work, 1.3% (0.9-1.9)
▪ social, 1.3% (1.0-1.7%).
Secondary attack rates (SAR, 95% credible interval), based on symptom-based PCR testing plus serology testing (Using Bayesian modelling adjusting for differential testing rates among consenting and non-consenting contacts):
▪ household, 11 (9–14) per 100 household contacts
▪ work, 5 (3–8) per 100 work contacts
▪ social, 4 (3–5) per 100 social contacts.
Risk factors association with transmission (n=584 household contacts, including n=89 cases and n=495 controls):
<table>
<tr><th>Risk factor</th><th>Univariate, OR (95% CI)</th><th>Multivariate, OR (95% CI)</th></tr>
<tr><td>> 35 years</td><td>1.30 (0.82–2.06)</td><td>0.99 (0.54–1.83)</td></tr>
</table>
</td>
<td>Restrictive measures:
From 13 March onwards, a range of restrictive measures were implemented in Singapore including:[67]
▪ travel restrictions
▪ mass gathering ban
▪ stay at home order
▪ closure of all non-essential businesses
▪ closure of all public amenities
▪ limited capacity on public transport.</td>
<td>Bayesian analysis of serology and symptom data obtained from 1150 close contacts (524 household contacts, 207 work contacts, and 419 social contacts) estimated that a symptom-based PCR-testing strategy missed 62% (95% credible interval 55–69) of COVID-19 diagnoses, and 36% (27–45) of individuals with SARS-CoV-2 infection were asymptomatic</td>
</tr>
</table>

Risk factors under investigation

- age group
- sex
- number of COVID-19 cases individual came into contact with
- relationship with COVID-19 case
- direct contact
- indirect contact
- sharing of meals
- sharing of bedroom
- sharing of toilet
- sharing of vehicle
- duration that a COVID-19 cases spoke to individual
- mask worn by COVID-19 case
- mask worn by individual.

Patient demographics:

Retrospective cohort study (n=7,518): The median age of close contacts was 33 years (IQR 21–49) and 3,922 (52·2%) were female.

	Household (n=1,779)	Work (n=2,231)	Social (n=3,508)
Age, median (IQR)	35 (22-53)	38 (30-49)	28 (10-47)
Female (%)	1,046 (58.9%)	1,064 (47.7%)	1,832 (52.2%)

Male	1.15 (0.73–1.80)	1.26 (0.73–2.18)
Contact with more than one COVID-19 case	1.89 (1.11–3.22)	1.65 (0.86–3.19)
Family member of a COVID-19 case but not spouse nor partner	2.17 (0.83–5.67)	1.52 (0.53–4.32)
Spouse or partner of a COVID-19 case	9.20 (3.50–24·17)	1.63 (0.45–5·93)
Received an object handed over by a COVID-19 case or touched the same surface or surfaces immediately after a COVID-19 case, or both	4.34 (2.25–8.37)	1.67 (0.77–3.64)
Shared a meal without involving any of the following: eating from the same plate, drinking from the same cup, or eating with the same utensils	2.47 (1.30–4.72)	1.03 (0.48–2.21)
Shared a meal involving one or more of the following: eating from the same plate, drinking from the same cup, or eating	4.90 (2.69–8.90)	1.29 (0.60–2.80)

with the same utensils		
Used the same toilet as a COVID-19 case but did not share a bedroom	1.78 (0.84–3.79)	1.11 (0.49–2.54)
Shared a bedroom with a COVID-19 case but did not use the same toilet	7.23 (3.23–16.18)	5.38 (1.82–15.84)
Shared a bedroom and used the same toilet as a COVID-19 case	10.62 (5.84–19.33)	5.05 (1.85–13.79)
Took the same vehicle as a COVID-19 case	2.38 (1.48–3.81)	0.84 (0.46–1.52)
COVID-19 case spoke for <30 min	4.07 (2.26–7.32)	3.91 (2.09–7.34)
COVID-19 case spoke for ≥30 min	14·19 (7·55–26·64)	7·86 (3·86–16·02)

Risk factors association with transmission (n=664 non-household contacts, n=53 cases and n=611 controls):

Risk factor	Univariate, OR (95% CI)	Multivariate, OR (95% CI)

> 35 years	0.89 (0.51–1.57)	0.69 (0.37–1.29)
Male	1.21 (0.69–2.13)	1·52 (0.82–2.83)
Contact with more than one COVID-19 case	4.50 (2.51–8.06)	3.92 (2.07–7.40)
Had direct physical contacts with a COVID-19 case	1.66 (0.94–2.94)	1.10 (0.55–2.19)
Received an object handed over by a COVID-19 case or touched the same surface or surfaces immediately after a COVID-19 case, or both	2.27 (1.27–4.05)	1.24 (0.62–2.46)
Shared a meal without involving any of the following: eating from the same plate, drinking from the same cup, or eating with the same utensils	1.83 (0.87–3.87)	1.04 (0.44–2.46)
Shared a meal involving one or more of the following: eating from the same plate, drinking from the same cup, or eating	2.86 (1.50–5.46)	1.45 (0.63–3.31)

with the same utensils		
Used the same toilet as a COVID-19 case	2.03 (1.06–3.88)	1.03 (0.48–2.18)
Took the same vehicle as a COVID-19 case	3.94 (2.21–7.04)	3.07 (1.55–6.08)
COVID-19 case spoke for <30 min	2.10 (1.01–4.34)	2.50 (1.15–5.44)
COVID-19 case spoke for ≥30 min	3.39 (1.65–6.97)	2.67 (1.21–5.88)
COVID-19 case or cases wore a mask during all contact episodes	1.55 (0.70–3.43)	Not conducted
Individual wore a mask during all contact episodes	1.53 (0.62–3.77)	Not conducted

<table>
<tr><th>Study descriptors</th><th>Study characteristics</th><th>Primary outcome</th><th>Restrictive measures</th><th>Other relevant findings</th></tr>
<tr>
<td>Author/organisation:

Takaya et al.

DOI:

10.1017/S0950268820002496

Study design:

Retrospective cohort study (peer reviewed).

Country:

Japan

Date of data collection:

09 March 2020 – 26 April 2020.</td>
<td>Research question/aim :

To describe the demography of nightlife clusters and analyse the association between exposure to nightlife businesses and SARS-CoV-2 PCR test results.

Sample size:

1,517 RT-PCR tests for 1,489 individuals.

Setting or activity under investigation
bars and pubs
host and hostess clubs
nightclubs and live music clubs
karaoke bars
commercial sex businesses.
Patient demographics:

<table>
<tr><th></th><th>Nightlife group (n=196)</th><th>Non-nightlife group (n=1,321)</th></tr>
<tr><td>Age, median (IQR)</td><td>31 (25-38)</td><td>39 (29-51)</td></tr>
<tr><td>Male (%)</td><td>146 (74.5)</td><td>721 (54.6)</td></tr>
<tr><td>Female (%)</td><td>50 (25.5)</td><td>600 (45.4)</td></tr>
</table></td>
<td>Comparator groups:

All patients who underwent a SARS-CoV-2 PCR test at an outpatient clinic from 9 March to 26 April 2020 were included in the study

The nightlife group was defined as those who had worked for nightlife businesses within one month before symptom onset or had visited those businesses within one month before symptom onset. Nightlife businesses included bars and pubs, host and hostess clubs, nightclubs and live music clubs, karaoke bars and commercial sex businesses. The non-nightlife group had not worked or visited any of these businesses in the month before symptom onset.

Main finding:

The nightlife group's proportion of positive tests was 63.8% (125/196). In the unmatched non-nightlife group, the positivity rate was 15.7% (207/1,321).

All patients in the nightlife group were matched to similar patients in the non-nightlife group, resulting in improved covariate balance in the matched group. After matching (for age, sex, nationality, comorbidity, severity, day of illness, exposure, overseas travel and being a</td>
<td>Restrictive measures:

Japan adopted a cluster-focused approach to tackle the COVID-19 outbreak. The unique focus on clusters was based on the finding that a small number of COVID-19 patients were responsible for multiple cases, thus forming patient clusters, in 'three Cs' (close contact in a closed and crowded space) environments. The Japanese health authorities have emphasised the cluster concept and requested the public to avoid such 'three Cs' environments. Since mid-March, the number of cases without an epidemiological link had increased in urban areas. On 30 March, the governor of Tokyo asked the citizens to refrain</td>
<td>N/A</td>
</tr>
</table>

		healthcare worker), the proportion of positive SARS-CoV-2 PCR tests in the nightlife group was significantly higher than that in the non-nightlife group (nightlife, 63.8%; non-nightlife, 23.0%; $p < 0.001$).	from visiting nightlife businesses.	

Study descriptors	Study characteristics	Primary outcome	Restrictive measures	Other relevant findings
Author/organisation: Wu et al. **DOI:** 10.1016/j.puhe.2020.05.016 **Study design:** Retrospective cohort study (peer reviewed). **Country:** China (Hangzhou in Zheijang province). **Date of data collection** 23 January 2020 – 28 February 2020.	**Research question/aim** : To determine the rate of secondary infection among contacts of individuals with confirmed COVID-19 in Hangzhou according to the type of contacts, the intensity of contacts, and their relationship with the index patient. **Sample size:** 2,994 contacts of 144 confirmed COVID-19 cases. 82 of these contacts (2.7%) became infected. **Setting or activity under investigation** Contact type: Shared transport/visit/medical care, dined together, household contact, Contact setting: medical institution, public place, workplace/education/entertainment, home setting. **Patient demographics:** Men, 1,464 (48.9%) Women, 1,530 (51.1%)	**Risk of infection with SARS-CoV-2 per setting/activity, OR (95% CI)** **Contact type:** Brief contact (undefined) with index case, OR=1 (reference) Shared transport, visit, medical care, OR=3.57 (95% CI, 1.42-8.98) Dined together, OR=2.64 (95% CI, 0.88-7.90) Household, OR=41.74 (95% CI, 17.69-98.49) *Relationship to the index case:* Healthcare provider or patient, OR=1 (reference) Co-worker, friend, teacher, student, neighbour, OR=4.12 (95% CI, 0.96-17.7) Family, OR=31.61, (95% CI, 7.69-130.01) **Contact setting:** Medical institution, OR=1 (reference) Public place, OR=5.32 (95% CI, 1.20-33.25) Workplace, educational institution, place of entertainment, OR=6.67 (95% CI, 1.34-33.25) Home and environs, OR=17.25 (95% CI, 4.20-70.77)	On 23 January, Zheijang province declared a major public health emergency and introduced 10 policies including vigorously promoting public awareness on epidemic prevention, restricting public gatherings, and taking measures to prevent hospital-acquired infections to curb the transmission of SARS-CoV-2 infection.	N/A

	Age: NR			

Study descriptors	Population characteristics	Primary outcome	Restrictive measures in place	Other relevant findings
Author/organisation: Yang et al. **DOI:** 10.3760/cma.j.cn112338-20200223-00153 **Study design:** Retrospective cohort study (peer reviewed). **Country:** China (outside Hubei). **Date of data collection:** 1 January 2020 – 20 February 2020.	**Research question/aim** : To collect information on the clustered epidemic situation of new coronavirus pneumonia, and analyse the exposure characteristics, transmission mode, incubation period and other indicators of the clustered epidemic, and conducted data on 2 typical clustered epidemics. **Sample size:** 377 clusters, involving 1,719 cases. **Setting or activity under investigation** Any setting except medical institutions. **Patient demographics:** Men, 840 (48.9%). Women, 879 (51.1%). Age range, 8 months-90 years.	**Number of clusters per setting:** Family setting: 297 clusters (79% of total), median cases per cluster=4 Meals/gatherings: 39 clusters (10%), median cases per cluster=5 Shopping malls/supermarkets: 23 clusters (6%), median cases per cluster=13 Work setting: 12 clusters (3%), median cases per cluster=6 Transportation: 6 clusters (2%), median cases per cluster=6.	On 23 January, Wuhan issued a lockdown notice. Not all regions in China enforced strict restrictive measures.[70] Hence data from this study is both from periods when there were no restrictions (pre-lockdown) and also when restrictions of varying degrees were implemented.	

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