Outdoor Transmission of SARS-CoV-2 and Other Respiratory Viruses, a Systematic Review

Tommaso Celeste Bulfone, MS,[a] Mohsen Malekinejad, MD, DrPh,[b] George W. Rutherford, MD, AM, [b,c] Nooshin Razani MD, MPH[b,c,*]

a. Joint Medical Program, University of California, Berkeley - University of California, San Francisco. 2121 Berkeley Way, Room 5302 Berkeley, CA 94720-7360, USA.
b. Department of Epidemiology and Biostatistics, University of California, San Francisco. 550 16th St 2nd floor, San Francisco, CA 94158, USA
c. Department of Pediatrics, University of California, San Francisco

Corresponding author: Nooshin Razani, MD 550 16th St 2nd floor, San Francisco, CA 94158, nooshin.razani@ucsf.edu, 415-722-1915

Summary:

This systematic review found that while outdoor environments do seem at lower risk for transmission of SARS-CoV-2 and other respiratory viruses than indoor environments, there are data showing that infection transmission is possible outdoors, thus warranting further rigorous investigation.

Abstract

Background

While risk of outdoor transmission of respiratory viral infections is hypothesized to be low, there is limited data of SARS-CoV-2 transmission in outdoor compared to indoor settings.

Methods

We conducted a systematic review of peer-reviewed papers indexed in PubMed, EMBASE and Web of Science and pre-prints in Europe PMC through August 12th, 2020 that described cases of human transmission of SARS-CoV-2. Reports of other respiratory virus transmission were included for reference.

Results

Five identified studies found that a low proportion of reported global SARS-CoV-2 infections have occurred outdoors (<10%) and the odds of indoor transmission was very high compared to outdoors (18.7 times; 95% CI 6.0, 57.9). Five studies described influenza transmission outdoors and two described adenovirus transmission outdoors. There was high heterogeneity in study quality and individual definitions of outdoor settings which limited our ability to draw conclusions about outdoor transmission risks. In general, factors such as duration and frequency of personal contact, lack of personal protective equipment and occasional indoor gathering during a largely outdoor experience were associated with outdoor reports of infection.

Conclusion

Existing evidence supports the wide-held belief that the the risk of SARS-CoV-2 transmission is lower outdoors but there are significant gaps in our understanding of specific pathways.

Keywords: coronaviruses, SARS-CoV-2, COVID-19, transmission, outdoor

Background

Recommendations about methods to curb transmission of the severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) beyond wearing masks and maintaining social distance have varied, especially regarding outdoor transmission.[1] This variability reflects a general lack of information on how SARS-CoV-2 is transmitted outdoors.

Outdoor spaces generally allow for more physical distancing, which mitigates the risk of virus transmission through larger respiratory droplets [2]. Outdoor spaces allow for airflow, ventilation, and lack of recycled air, which all minimize the theoretical risk of aerosol transmission through smaller respiratory droplets. While aerosol spread in community settings is controversial, emerging data suggest that indoor recycled air can spread SARS-CoV-2 — with examples of spreading events in a restaurant in Guangzhou [3], at an indoor choir practice in Skagit, Washington, USA [4], at a South Korean call center [5], at meat-packing plants in the USA [6] and in a nursing home in the Netherlands [7]. In areas with low ventilation, aerosolized droplets have the capacity to linger for longer before being inhaled or falling to a surface, which could result in fomite transmission [8]. In enclosed environments, low humidity, air conditioning, and low UV light may all contribute to longer survival of viral particles [9]. Outdoor environments also generally have fewer high touch surfaces that may harbor the virus. UV light, present outdoors from sunlight, results in a ten-fold decrease in virus survival on surfaces [10]. Finally, indoor environments may increase host susceptibility; the low indoor humidity has been associated with slower host ciliary clearance and complications such as pneumonia, and lack of sunlight has been associated with lower vitamin D levels [11]. For these reasons, the risk of virus transmission in outdoor locations has been hypothesized to be lower than in indoor spaces.

We sought to quantify the risk of SAR-CoV-2 transmission in outdoor settings. We conducted a systematic review of the literature on transmission of SARS-CoV-2 to better understand the risks of outdoor transmission. Where data was available, we estimated the risk of outdoor compared to indoor transmission. Anticipating a paucity of data on SARS-CoV-2, we chose a broad search strategy that included other human beta coronaviruses and respiratory viruses.

Methods

Search strategy and selection criteria

Data for this review were identified by searches of PubMed, EMBASE, Web of Science, as well as preprints available in Europe PMC [12]. Details of our search strategies and eligibility criteria can be found in our protocol published on August 3rd, 2020 on PROSPERO (ID: 183826). The search was conducted on June 17th, 2020, and because of the rapidly expanding data on SARS-CoV-2, the search was repeated to include most recent literature on August 12th, 2020.

Exposures and outcomes

The exposure of interest - outdoor gatherings - was defined as persons congregating outdoors for work, social or recreational activities (Supplementary Material 1 for our full search strategy). The outcome of interest included cases of transmission of SARS-CoV-2 or other respiratory viruses identified by a case report, illness, or mortality. We also included secondary outcomes of clusters or outbreaks of cases. Our search included any viral infection that can be spread by respiratory droplets and, in addition to SARS-CoV-2, included the other two recognized human beta-human coronaviruses viruses (SARS-CoV-1 and Middle East Respiratory Syndrome), human influenza viruses, adenoviruses, rhinoviruses, human metapneumoviruses, and respiratory syncytial virus.

We included studies (experimental or observational with empirical data collection) that described human-to-human transmission of respiratory viruses between humans in an outdoor setting, any review of these studies, and any study (experimental or observational) that compared respiratory viral transmission among humans in an outdoor versus indoor settings.

We excluded reviews of previously published data, studies of exclusively indoor outbreaks, outdoor outbreaks within animal populations or between animals and humans, and outbreaks where the site of transmission was not listed or was unclear. We also excluded studies limited to built environments (homes, apartment buildings, military barracks), hospitals, or forms of transportation (airplanes, trains, buses, cars, ships).

Data Selection and Extraction

After removing duplicate records, one author (TCB) reviewed all downloaded citations based on their titles and pre-specified inclusion criteria. A second co-author (MM) reviewed a 5% random sample of the excluded titles (rejected from initial search results) for quality control. Two authors (TCB and NR) then independently screened the titles, abstracts and descriptor terms and compared and discussed discrepancies until consensus was reached; a third author (MM) served as an arbiter when needed. Two authors (TCB and NR) then independently inspected the full texts of the remaining studies for relevance based on exposure, design and outcome measures to select the included papers, and discussed discrepancies until consensus was reached with a third author (MM) serving as arbiter. We used Endnote X9.3.2 (Clarivate

Analytics, Philadelphia, Pennsylvania, USA) and Rayyan (Qatar Computing Research Institute, Doha, Qatar) web-based software to manage search results [13].

Two authors (TCB and NR) extracted the following data from each paper into a pre-piloted data extraction form in Excel spread sheets : complete citation, study location, study design, details of participants (risk group or groups, sample size), exposure details (type of gathering, characteristics of gathering place, number of people, duration, proportion of time spent outdoors, amount if any of indoor transmission, how the non-exposure state (indoors) was defined, outcomes (numerators and denominators associated with each outcome, definitions and descriptions of outcomes provided in papers, details of how outcomes were assessed, individual cases of infection and/or large spreading events, mortality), methodological details (sample characteristics, how the information was gathered, how the outbreak was investigated), and details related to bias assessment.

Results

The combined searches yielded 10,912 unique citations, of which 12 studies met our inclusion criteria. Nine studies were identified from the June 17th search, two from the August 12th, and one from a targeted search. Out of the 12 that met our inclusion criteria, five were pertaining to SARS-CoV-2 **(Table 1 and 2)**, five reported on influenza or influenza-like viruses **(Table 3)**, and two reported on adenovirus transmission. Of note, 33 studies were excluded because they did not specify the location of transmission (Supplementary Material 2). The PRISMA diagram is shown in **Figure 1**.

Five studies related to SARS-CoV-2 transmission found that less than 10 percent of reported transmission occurred in outdoor settings, less than 5% of cases were related to outdoor occupations, and the odds of transmission or super spreading are much lower outdoors **(Table 1)** [14–17].

Of 318 identified outbreaks involving three or more cases in China reported to local Municipal Health Commissions from January 4 to February 11, 2020, Qian et al. found that all occurred in indoor environments [14]. They reported a single transmission that occurred outdoors (one case of outdoor transmission out of 7,324 total reported cases). This report, however, might be affected by strict interventions prohibiting mass gatherings outdoors, which may have contributed to the low number of cases contracted outdoors. Additionally, relying on local health department reports may have led to underestimates of the total number of transmissions, especially those which were asymptomatic [14].

Nishiura et al. [15] analyzed the transmission pattern of COVID-19 reported through February 28, 2020 (11 clusters and sporadic cases) in Japan. They concluded that the odds of a primary case transmitting COVID-19 in a closed environment were 18.7 times greater compared to outdoor setting (defined as an open-air environment) (95% confidence interval [CI]: 6.0, 57.9). The odds of a single case spreading to 3 or more individuals, which they defined as a super spreader event, in closed environments compared to open air were as 32.6 (95% CI: 3.7, 289.5). This report, however, included no description of the context or location of the outdoor transmission nor were any raw data provided. It is unclear whether this report is relying on proportions, which again, may be subject to the fact that fewer people would have been outdoors during winter months in Japan .

Leclerc et al. [16] reviewed 201 transmission clusters of COVID-19 world-wide that had been reported up to March 30, 2020. The vast majority of these transmissions were associated with “indoor” or “indoor/outdoor” settings (197/201 clusters or 21/22 locations). The one “outdoor” setting was at multiple construction sites in Singapore, where four outbreaks occurred.

Lan et al. [17] investigated 103 possible work-related cases of COVID-19 among a total of 690 local cases in six Asian countries or regions, including Hong Kong, Japan, Singapore, Taiwan, Thailand, and Vietnam. In this paper, construction workers in Singapore constituted only 5% of the total work-related transmissions. While this paper did not explicitly state whether the location of work-related transmission was outdoor or indoors, it was included based on Leclerc’s classification of the same construction workers as an “outdoor” setting. This does not rule out that that transmission may have occurred in indoor locations at construction sites.

Szablewski et al. [18] report SARS-CoV-2 transmission at an overnight camp in Georgia, USA, where attack rates increased with increasing length of time at the camp, and with co-housing. Staff members, who stayed the longest at camp, had the highest attack rate (56%). The outbreak was clustered by cabin assignments, which suggests a high likelihood of transmission in indoor spaces during overnight cabin stays rather than during outdoor activities during the day. The authors state that non-pharmaceutical interventions such as cohorting and adults wearing masks during the day, were not protective, although no further information is given about this claim.

While there is high heterogeneity in the studies describing outdoor transmission of SARS-CoV-2, the studies we found highlight the conditions of outdoor exposure and transmission. The location and context of SARS-CoV-2 transmissions reported in this review are summarized in **Table 4**. Among these are examples of transmissions at a gathering in a park, but over multiple days with the same people, and at a camp, which lasted for several days and had indoor housing components.

Five other studies included in **Table 3** describe outdoor transmission of influenza or influenza-like viruses. Summers et al. [19] conducted a historical analysis of a large outbreak of the 1918 influenza virus on a military troop ship in July 1918. The outbreak involved over 1000 of the 1,217 crew members and caused 68 deaths. Analysis of factors that might have contributed to mortality revealed a significant association between individuals who slept indoors, in cabins with bunks (mortality of 146.1/1,000 population), versus individuals who slept in hammocks in open-air areas (mortality of 34.1/1,000 population). This study is of particular interest because the duration of exposure and distance between individuals was held constant. This was one of the few studies which investigated potential confounders such as age and social class – mortality changed with age, but not with social class or rurality. Age did not change the discrepancy in deaths seen outdoors compared to indoors.

Pestre et al. [20] conducted a retrospective analysis of a 2009 H1N1 influenza outbreak at a summer camp in France. Investigations revealed that all febrile individuals had travelled together in the same train wagon to reach camp, suggesting that the enclosed space facilitated transmission. The three individuals out of 32 that had not travelled in the same train wagon as all the other participants never developed symptoms, even though they were still present at camp for two days with all other infected individuals - presumably mostly in outdoor spaces.

Finally, three manuscripts about respiratory illnesses at mass open-air gatherings emphasized that while influenza outbreaks were uncommon, the duration of the event (multi-day over single day) and communal housing were risk factors for outbreaks (**Table 3**). [21–23] Rainey et al. concluded that all reported outbreaks in summer camps had social contact and communal housing, none were reported without a shared housing component.[21] Of note, no single-day mass gathering related outbreaks were detected in the 72 outbreaks they detail. Figueroa et al. also did not identify any single day event-related outbreaks.[22] Botelho et al. found four outbreaks of Influenza A (H1N1) and one of Influenza A and B; all events with an outbreak were multi-day sport events while single-day events had none.[23]

Two articles discussed adenovirus outbreaks associated with lakes [24] and outdoor swimming pools [25]. In both studies respiratory viral infection occurred in swimmers and in others who did not swim, such as fellow camp attendees and family members, suggesting human-to-human transmission prevalently occurring outdoors.

Discussion

While the studies included in this review were highly heterogeneous, ranging in methodology, definition of "outdoor" transmission, and virus studied, several common factors were identified. The studies with direct comparison of SARS-CoV-2 location of transmission reported dramatically lower proportions occurring outdoors. The exact determinants of outdoor transmission that can be gleaned from this review are limited, the cases of outdoor transmission of SARS-CoV-2 we identified were affected by the duration of exposure, frequency of exposure, density of gathering, whether maks were used, and were confounded by the possibility of indoor transmission.

Historical evidence gleaned from influenza outbreaks further support the lower risk of transmission outdoors. Summers et al. showed that influenza mortality on a ship was significantly lower outdoors (sleeping in hammocks) compared to indoors (sleeping in cabins). While mortality does not provide direct information about transmission, it serves as a useful proxy. Outcomes from several investigations of influenza outbreaks during mass outdoor gatherings suggest that outdoor, single day events without communal sleeping arrangements have lower risks of influenza transmission than multi-day events with indoor components [21–23].

These findings, as well as reports of influenza outbereaks and adenovirus outbreaks in outdoor bodies of water, suggest that while outdoor transmission is less common than indoor, it is not impossible. Case reports identified after our review was completed provide further evidence that high density outdoor gatherings, particularly with low mask use, may lead to higher transmission rates. Miron et. al noted that incidence of COVID-19 cases was significantly higher in 14 out of 20 counties that had a large outdoor gathering 15 days prior.[26] Dave et al. estimates that in the three weeks following the start of the Sturgis motorcycle rally started on August 7th 2020, South Dakota, USA, an multi-day event with 500,000 participants, cases grew more in counties with weak mitigation policies than those with strong mitigation policies (such as closure of restaurants and bars, or mask-wearing mandates) as participants returned to their homes [27]. In contrast, although COVID-19 rates increased in the three weeks following the mass protests in the United States [28], the uptick in cases due to these events was less than expected because social distancing and masking measures were more widespread [29]. The importance of protective measures is further exemplified by the outdoor outbreak that occurred at the White House Rose Garden event on September 26th 2020, where few of the 200 attendees were wearing masks or maintaining social distancing measures.[30]

Of note, our search did not find any studies on the transmission of COVID-19 in settings of outdoor agricultural work. In California prevalence of COVID-19 for agricultural workers is two to three times higher than the rate for workers in all other industries [31]. The experience of agricultural workers suggests that crowded working or sleeping conditions may be a substantive risk factor for transmission, but the contribution of work in outdoor spaces to transmission risk has not been assessed. We found that outdoor, single day events without communal sleeping arrangements have lower risks of transmission compared to multi-day, mass outdoor gatherings in the spread of influenza [21–23].

In order to better characterize the risks of outdoor SARS-CoV-2 exposure, future studies should fill the research gaps we have identified in this review. First, many research studies we identified did not report the location of transmission at all. This may be because understanding relationships between cases is more important than the location of interaction, or may be related to practical challenges in contact tracing outdoors. Second, it is difficult to isolate an outdoor exposure to a virus. While outdoor gatherings could be largely safe, if they are accompanied by time in indoor locations such as cabins or trains, it might be challenging to identify exact location of transmission. Szablewski et al., which was included in our review, while the summer camp may have been largely outdoors, it does not preclude from exposure in the dining halls or cabins. As for construction sites, once a building is framed and enclosed, it may be considered indoor work, which may in fact be the majority of the work. Third, in many reports published early in the SARS-CoV-2 pandemic, the measured outcome was "illness or death" due to viral infection, not SARS-CoV-2 infection itself, which was rarely assessed. If asymptomatic infections are more likely to occur outdoors, this could represent a systematic bias. Fourth, the definition of being “outdoors” is ambiguous, and the effect of exposure is likely modified by variable proximity to and contact with others. Fifth, in order to test the hypothesis that the risk of infection is lower outdoors, future research should collect data about time spent indoors versus outdoors. Given that 90% of time is spent indoors in high-and-middle income countries [32], then it would be expected that 90% of transmission to occur indoors, all else being equal. Lastly, there are few data that examine how respiratory droplets spread outdoors, such as how far they travel during running, biking, or during windy conditions. A study examined these variables but was calculated with no account of ventilation, sunlight, or humidity. [33]

Finally, most of the transmission events we identified in the literature did not report the socioeconic status of those impacted. Spreading events often occur in settings where marginalized and disempowered populations live or work such as lower-income, higher density urban settings, work settings such as meat packing plants, or even prisons [34]. While there are multiple reasons for the disproportionate impacts of COVID-19 in these populations, we postulate that lack of opportunity to move high-risk activities outdoors may be one of them. [35,36] While it was our intention to further explore this hypothesis by analyzing sub-group socio-economic and ethnicity data in the studies included in this review, the studies did not include these metrics.

Future studies could compare SARS-CoV-2 case rates at outdoor gatherings to known rates for indoor gatherings. There are several examples of studies that estimate the risk of indoor transmissison [37–39] which have ranged from 10.3% (95% confidence interval [CI] 5.3% – 19.0%) in a study of trains in China to 78% in a church in Arkansas [38]. Accurate estimation of the risk of outdoor transmission will require determining person-time at risk for infection, incidence rate ratios, and more nuanced information about the exposure environment; these data are still lacking.

Better understanding of how SARS-CoV-2 is transmitted outdoors is needed to inform sound policies that reconcile shelter-in-place orders with the many health benefits associated with time spent outdoors [40]. This is particularly relevant to outdoor parks and recreation agencies, which seek clear guidance on how being outdoors has a low risk of transmission. Other policy implications are to encourage moving essential activities outdoors, with appropriate masking and social distancing measures, given that transmission can still occur outdoors. The long term and potentially deleterious social and emotional effects of school closures can be potentially mitigated if, for example, it is known that outdoor schooling is a viable alternative. Finally, encouraging outdoor time may serve as a harm reduction model in allowing people to congregate, and therefore better tolerate long-term shelter in place mandates.

This systematic review has several limitations. The few and heterogenous studies on outdoor transmission of respiratory viruses had used various metrics, exposures and outcomes, making it challenging to compare findings quantitatively. The low proportion of outdoor COVID-19 cases may reflect the general decrease in outdoor activities since strict lockdowns were enacted in the countries surveyed. Relying on reports of symptomatic infections may under-represent asymptomatic cases that occur outdoors. If the viral inoculum affects the severity of respiratory viral infection, an outdoor exposure may reduce the viral inoculum to which the individual is exposed and therefore the subsequent clinical impact of the disease. If this theory were true for SARS-CoV-2, it may increase the proportion of infections that are asymptomatic.[41] The studies in this review did not contain much information about potential confounders such as the age of infected individuals, activities in which they participated, ethnicity, or social class. There was minimal information on mitigation efforts such as masks and social distancing and how that may have impacted/influenced viral transmission. This review did not explicitly include gray literature (such as case reports from health departments, lay newspaper sources) in its search strategy, as other comprehensive reviews of transmissions have done.[16] Including preprints may have decreased our risk of information bias.

Conclusion

While it has been acknowledged that spending time outside has general health benefits, our review posits that there are also benefits in reducing transmission of SARS-CoV-2 by reducing exposure time (substituting time indoors with time outdoors). These results suggest that moving activities to outdoor settings may reduce infections and ultimately save lives. However, it is important to note that infections are possible outdoors and the advantage may be overtaken by relaxed mitigation efforts.

Funding

Tommaso Celeste Bulfone, MS, was supported by a Shoeneman grant at the UC Berkeley-UCSF Joint Medical Program, Mohsen Malekinejad, MD DrPH and Nooshin Razani, MD were supported by grants from the REI Foundation and the Long Foundation. Funders played no role in the decision to conduct this study, the analysis, findings, or writing of this manuscript. The authors do not have commercial or other associations that might pose a conflict of interest.

References

1. Razani N, Radhakrishna R, Chan C. Public lands are essential to public health during a pandemic [Internet]. Pediatrics. American Academy of Pediatrics; 2020 [cited 2020 Nov 11]. Available from: https://doi.org/10.1542/peds.2020-1271

2. Doremalen N Van, Bushmaker T, Morris DH, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1 [Internet]. N. Engl. J. Med. Massachussetts Medical Society; 2020 [cited 2020 Aug 16]. p. 1564–1567. Available from: http://www.nejm.org/doi/10.1056/NEJMc2004973

3. Lu J, Gu J, Gu J, et al. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. Emerg Infect Dis [Internet]. Centers for Disease Control and Prevention (CDC); **2020** [cited 2020 Aug 15]; 26(7):1628–1631. Available from: https://doi.org/10.1155/2013/493960

4. Hamner L, Dubbel P, Capron I, et al. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020. MMWR Morb Mortal Wkly Rep [Internet]. Centers for Disease Control MMWR Office; **2020** [cited 2020 Aug 15]; 69(19):606–610. Available from: http://www.cdc.gov/mmwr/volumes/69/wr/mm6919e6.htm?s_cid=mm6919e6_w

5. Park SY, Kim YM, Yi S, et al. Coronavirus Disease Outbreak in Call Center, South Korea. Emerg Infect Dis [Internet]. NLM (Medline); **2020** [cited 2020 Aug 15]; 26(8):1666–1670. Available from: https://doi.org/10.3201/eid2608.201274

6. Jamous F, Meyer N, Buus D, et al. Critical Illness Due to Covid-19: A Description of the Surge in a Single Center in Sioux Falls. S D Med [Internet]. NLM (Medline); **2020** [cited 2020 Sep 17]; 73(7):312–317. Available from: https://pubmed-ncbi-nlm-nih-gov.ucsf.idm.oclc.org/32805781/

7. Man P de, Paltansing S, Ong DSY, Vaessen N, Nielen G van, Koeleman JGM. Outbreak of COVID-19 in a nursing home associated with aerosol transmission as a result of inadequate ventilation. Clin Infect Dis [Internet]. Clin Infect Dis; **2020** [cited 2020 Sep 17]; . Available from: http://www.ncbi.nlm.nih.gov/pubmed/32857130

8. Wei J, Li Y. Airborne spread of infectious agents in the indoor environment. Am J Infect Control [Internet]. Mosby Inc.; **2016** [cited 2020 Aug 20]; 44(9):S102–S108. Available from: /pmc/articles/PMC7115322/?report=abstract

9. Willem L, Kerckhove K van, Chao DL, Hens N, Beutels P. A Nice Day for an Infection? Weather Conditions and Social Contact Patterns Relevant to Influenza Transmission. PLoS One [Internet]. Public Library of Science; **2012** [cited 2020 Aug 15]; 7(11). Available from: /pmc/articles/PMC3498265/?report=abstract

10. Kanzawa M, Spindler H, Anglemyer A, Rutherford GW. Will Coronavirus Disease 2019 Become Seasonal? J Infect Dis [Internet]. NLM (Medline); **2020** [cited 2020 Sep 17]; 222(5):719–721. Available from: https://pubmed-ncbi-nlm-nih-gov.ucsf.idm.oclc.org/32609334/

11. Moriyama M, Hugentobler WJ, Iwasaki A. Annual review of virology seasonality of respiratory viral infections. Annu Rev Virol [Internet]. Annual Reviews Inc.; **2020** [cited 2020 Aug 15]; 7. Available from: https://doi.org/10.1146/annurev-virology-012420-

12. Gou Y, Graff F, Kilian O, et al. Europe PMC: A full-text literature database for the life sciences and platform for innovation. Nucleic Acids Res [Internet]. Oxford University Press; **2015** [cited 2020 Sep 17]; 43(D1):D1042–D1048. Available from: https://pubmed-ncbi-nlm-nih-gov.ucsf.idm.oclc.org/25378340/

13. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev [Internet]. BioMed Central Ltd.; **2016** [cited 2020 Sep 8]; 5(1). Available from: https://link.springer.com/epdf/10.1186/s13643-016-0384-4

14. Qian H, Miao T, LIU L, Zheng X, Luo D, Li Y. Indoor transmission of SARS-CoV-2. medRxiv [Internet]. Cold Spring Harbor Laboratory Press; **2020** [cited 2020 Aug 15]; :2020.04.04.20053058. Available from: https://doi.org/10.1101/2020.04.04.20053058

15. Nishiura H, Oshitani H, Kobayashi T, et al. Closed environments facilitate secondary transmission of coronavirus disease 2019 (COVID-19). medRxiv [Internet]. Cold Spring Harbor Laboratory Press; **2020** [cited 2020 Aug 15]; :2020.02.28.20029272. Available from: https://doi.org/10.1101/2020.02.28.20029272

16. Leclerc QJ, Fuller NM, Knight LE, Funk S, Knight GM. What settings have been linked to SARS-CoV-2 transmission clusters? Wellcome Open Res [Internet]. F1000 Research Ltd; **2020** [cited 2020 Aug 15]; 5. Available from: /pmc/articles/PMC7327724/?report=abstract

17. Lan F-Y, Wei C-F, Hsu Y-T, Christiani DC, Kales SN. Work-related COVID-19 transmission in six Asian countries/areas: A follow-up study. Shaman J, editor. PLoS One [Internet]. Public Library of Science; **2020** [cited 2020 Aug 15]; 15(5):e0233588. Available from: https://dx.plos.org/10.1371/journal.pone.0233588

18. Szablewski CM, Chang KT, Brown MM, et al. SARS-CoV-2 Transmission and Infection Among Attendees of an Overnight Camp — Georgia, June 2020. MMWR Morb Mortal Wkly Rep [Internet]. **2020** [cited 2020 Aug 15]; 69(31):1023–1025. Available from: http://www.cdc.gov/mmwr/volumes/69/wr/mm6931e1.htm?s_cid=mm6931e1_w

19. Summers JA, Wilson N, Baker MG, Shanks DG. Mortality risk factors for pandemic influenza on New Zealand troop ship, 1918. Emerg Infect Dis [Internet]. Centers for Disease Control and Prevention; **2010** [cited 2020 Aug 15]; 16(12):1931–1937. Available from: /pmc/articles/PMC3294590/?report=abstract

20. Pestre V, Morel B, Encrenaz N, et al. Transmission by super-spreading event of pandemic A/H1N1 2009 influenza during road and train travel. Scand J Infect Dis [Internet]. Scand J

Infect Dis; **2012** [cited 2020 Aug 15]; 44(3):225–227. Available from: https://pubmed.ncbi.nlm.nih.gov/22148980/

21. Rainey JJ, Phelps T, Shi J. Mass Gatherings and Respiratory Disease Outbreaks in the United States – Should We Be Worried? Results from a Systematic Literature Review and Analysis of the National Outbreak Reporting System. Shaman J, editor. PLoS One [Internet]. Public Library of Science; **2016** [cited 2020 Aug 15]; 11(8):e0160378. Available from: https://dx.plos.org/10.1371/journal.pone.0160378

22. Figueroa A, Gulati RK, Rainey JJ. Estimating the frequency and characteristics of respiratory disease outbreaks at mass gatherings in the United States: Findings from a state and local health department assessment. PLoS One [Internet]. Public Library of Science; **2017** [cited 2020 Aug 15]; 12(10). Available from: https://pubmed.ncbi.nlm.nih.gov/29077750/

23. Botelho-Nevers E, Gautret P. Outbreaks associated to large open air festivals, including music festivals, 1980 to 2012. Eurosurveillance [Internet]. European Centre for Disease Prevention and Control (ECDC); **2013** [cited 2020 Aug 15]; 18(11). Available from: https://pubmed.ncbi.nlm.nih.gov/23517872/

24. McMillan NS, Martin SA, Sobsey MD, Wait DA, Meriwether RA, MacCormack JN. Outbreak of pharyngoconjunctival fever at a summer camp - North Carolina, 1991. J Am Med Assoc. **1992**; 267(21):2867–2868.

25. D'Angelo LJ, Hierholzer JC, Keenlyside RA, Anderson LJ, Martone WJ. Pharyngoconjunctival fever caused by adenovirus type 4: Report of a swimming pool-related outbreak with recovery of virus from pool water. J Infect Dis [Internet]. J Infect Dis; **1979** [cited 2020 Aug 15]; 140(1):42–47. Available from: https://pubmed.ncbi.nlm.nih.gov/222852/

26. Miron O, Yu K-H, Wilf-Miron R, Davidovitch N. COVID-19 infections following outdoor mass gatherings in low incidence areas: retrospective cohort study. medRxiv [Internet]. Cold Spring

Harbor Laboratory Press; **2020** [cited 2020 Nov 8]; :2020.10.22.20184630. Available from: https://doi.org/10.1101/2020.10.22.20184630

27. Dave D, Friedson AI, Mcnichols D, Sabia JJ. The Contagion Externality of a Superspreading Event: The Sturgis Motorcycle Rally and COVID-19 [Internet]. 2020. Available from: www.iza.org

28. Valentine R, Valentine D, Valentine JL. Relationship of George Floyd protests to increases in COVID-19 cases using event study methodology. J Public Health (Bangkok) [Internet]. Oxford University Press (OUP); **2020** [cited 2020 Sep 17]; . Available from: https://academic.oup.com/jpubhealth/advance-article/doi/10.1093/pubmed/fdaa127/5880636

29. Dave D, Friedson A, Matsuzawa K, Sabia J, Safford S. Black Lives Matter Protests, Social Distancing, and COVID-19 [Internet]. Cambridge, MA; 2020 Jun. Available from: http://www.nber.org/papers/w27408.pdf

30. Tracking the White House Coronavirus Outbreak - The New York Times [Internet]. [cited 2020 Nov 8]. Available from: https://www.nytimes.com/interactive/2020/10/02/us/politics/trump-contact-tracing-covid.html

31. Farmworkers Are Among Those at Highest Risk for COVID-19, Studies Show | COVID's Hidden Toll | FRONTLINE | PBS | Official Site [Internet]. [cited 2020 Sep 9]. Available from: https://www.pbs.org/wgbh/frontline/article/covid-19-farmworkers-among-highest-risk-studies-show/

32. Klepeis NE, Nelson WC, Ott WR, et al. The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol. **2001**; 11(3):231–252.

33. Blocken B, Malizia F, Druenen T Van, Marchal T. Towards aerodynamically equivalent COVID-19 1.5 m social distancing for walking and running. 2020.

34. Tai DBG, Shah A, Doubeni CA, Sia IG, Wieland ML. The Disproportionate Impact of COVID-19 on Racial and Ethnic Minorities in the United States. Clin Infect Dis [Internet]. Oxford University Press (OUP); **2020** [cited 2020 Sep 9]; . Available from: /pmc/articles/PMC7337626/?report=abstract

35. Klompmaker JO, Hart JE, Holland I, et al. County-level exposures to greenness and associations with COVID-19 incidence and mortality in the United States. medRxiv [Internet]. Cold Spring Harbor Laboratory Press; **2020** [cited 2020 Nov 8]; :2020.08.26.20181644. Available from: https://doi.org/10.1101/2020.08.26.20181644

36. Johnson TF, Hordley LA, Greenwell MP, Evans LC, Johnson TF. Effect of park use and landscape structure on COVID-19 transmission rates. medRxiv [Internet]. Cold Spring Harbor Laboratory Press; **2020** [cited 2020 Nov 8]; :2020.10.20.20215731. Available from: https://doi.org/10.1101/2020.10.20.20215731

37. Jing Q-L, Liu M-J, Zhang Z-B, et al. Household secondary attack rate of COVID-19 and associated determinants in Guangzhou, China: a retrospective cohort study. Lancet Infect Dis [Internet]. Elsevier BV; **2020** [cited 2020 Aug 20]; 0(0). Available from: https://doi.org/10.1016/S1473-3099

38. James A, Eagle L, Phillips C, et al. High COVID-19 Attack Rate Among Attendees at Events at a Church — Arkansas, March 2020. MMWR Morb Mortal Wkly Rep [Internet]. Centers for Disease Control MMWR Office; **2020** [cited 2020 Aug 20]; 69(20):632–635. Available from: http://www.cdc.gov/mmwr/volumes/69/wr/mm6920e2.htm?s_cid=mm6920e2_w

39. Hu M, Lin H, Wang J, et al. The risk of COVID-19 transmission in train passengers: an epidemiological and modelling study. Clin Infect Dis [Internet]. Oxford University Press (OUP);

2020 [cited 2020 Aug 20]; . Available from: https://pubmed.ncbi.nlm.nih.gov/32726405/

40. Kondo MC, Fluehr JM, McKeon T, Branas CC. Urban green space and its impact on human health. Int. J. Environ. Res. Public Health. MDPI AG; 2018.

41. Gandhi M, Rutherford GW. Facial Masking for Covid-19 — Potential for "Variolation" as We Await a Vaccine. N Engl J Med [Internet]. Massachusetts Medical Society; **2020** [cited 2020 Nov 11]; 383(18):e101. Available from: https://www.nejm.org/doi/full/10.1056/NEJMp2026913

Table 1. Comparison of respiratory virus transmission outdoors compared to indoors ordered by virus studied.

Outcome	Virus Studied	Estimate of effect		Relative estimate of effect	Number of participants in the study
		Outdoor	Indoor		
Number of cases [14]	SARS-CoV-2	2/7,324 cases	7,322/7,324 cases	<1% of transmissions happened outdoors	7,324 cases, totaling 318 outbreaks.
Number of cases [17]	SARS-CoV-2	4/103 cases	99/103 cases	5% of work-related cases occurred outdoors	103 possible work-related cases among a total of 690 local transmissions.
Odds of transmission [15]	SARS-CoV-2	*(Raw data not available)*	*(Raw data not available)*	Odds of transmission in closed environments 18.7 (95% CI: 6.0, 57.9) times greater than in open air	110 cases: 27 primary cases and 83 secondary cases
Number of super-spreading events and odds of transmission* [15]	SARS-CoV-2	1/7 super-spreading events	6/7 super-spreading events	Odds ratio of super spreading in closed environments: 32.6 (95%CI: 3.7, 289.5)	110 cases: 27 primary cases and 83 secondary cases
Number of cases [16]	SARS-CoV-2	95/10,926 cases	10,831/10,926 cases	<1% of transmissions happened outdoors	10,926 cases, totaling 201 events of transmission
Number of cases [20]	H1N1 2009 Influenza	0/3 cases	24/29 cases	Out of 32 total people in a holiday camp, 29 traveled together in a train wagon	32 people at a holiday camp
Mortality [19]	H1N1 1918 Influenza	28/820 deaths sleeping in hammocks outside, 34.1 persons/1,000	39/267, deaths sleeping in cabins inside, 146.1 persons/1,000	Risk Ratio of 4.28, 95% CI 2.69-6.81	Total of 1,217 people on the ship.

* superspreading defined as events where the number of secondary cases generated by a single primary case is greater than the 95th percentile of the distribution (i.e. transmission to three or more persons)

Table 2. Studies reporting outdoor SARS-CoV-2 transmission.									
Year	**Author**	**Location and Date**	**Sample Description**	**Design**	**Outcomes measured**	**Outdoor exposure**	**Outdoor findings**	**Indoor findings**	**Bias**
2020	Qian et al.	320 prefectural cities in China. Between 4 January and 11 February 2020	7,324 cases, 318 outbreaks	Retrospective analysis of all public health reports from local Municipal Health Commission website to determine location of transmission.	Location of transmissions, clusters and outbreaks. Cluster was defined as 3 or more infections that appear linked to the same infection venue. An outbreak was defined as a cluster in which a common index patient is suspected. Outbreaks were organized by relationship and also by location.	Open air	One outdoor transmission involving two cases in Shangqiu, Henan: a 27-year-old man had a conversation outdoors with an individual who had returned from Wuhan.	Of 318 identified outbreaks that involved 3 or more cases, they all occurred in indoor environments.	Relied on heterogenous case reports of the local health department, which might have missed cases because of differential allocation of resources or internal biases. Additionally, the data was collected partly after lock-down (started January 23rd in Wuhan), after which most people were indoors. There was no effort to access exact locations of infection. Not peer-reviewed at the time of review.
2020	Nishiura et al.	Seven prefectures in Japan. Start date of 28 February 2020	110 cases (27 primary cases, 83 secondary cases). Seven superspreading events identified.	Retrospective case investigation using contact tracing data.	Location and number of transmissions from primary to secondary cases. Super-spreading events defined as: number of	Open air	Odds of transmission in a closed environment was 18.7 times greater compared to an open-air environment (CI:	Out of seven superspreading events, six of these events (85.7%) took place in closed environments.	Small sample size and no raw data provided to support calculations of odds. Limitations were not discussed in the manuscript.

Table 2. Studies reporting outdoor SARS-CoV-2 transmission.

					secondary cases generated by a single primary case is greater than the 95th percentile of the distribution (i.e. transmission to three or more persons)		6.0, 57.9). The odds ratio of superspreading events in closed environments was as high as 32.6 (95% CI: 3.7, 289.5). One superspreading event occurred outdoors (not described).		Not peer-reviewed at the time of review.
2020	Leclerc et al.	Multiple world-wide locations, as of March 30th	201 events of transmission (clusters)	Review of all documented transmission clusters (world-wide) using literature review and open-source strategies	Settings of transmission clusters for 201 events	22 types of settings were determined. Outdoor locations were defined as "outdoor", while locations that were a mixture were defined as "indoor/outdoor". Indoor locations were defined as "indoor".	The transmissions in the only "outdoor" setting occurred in four outbreaks at outdoor construction sites in Singapore, totaling 95 cases. Updated results additionally revealed: - one transmission occurred while jogging in Codogno, Italy (non-peer re-viewed source) - Twenty cases in an outdoor park in Münster, Germany (non-peer reviewed source)	10/22 locations defined as indoor/outdoor, 11/22 defined as indoor. A total of 197 events occurred in these settings, totaling 10,831 cases.	Included reports from some non-peer reviewed sources (eg. local media outlets for the jogging and outdoor park transmission reports), which might have been individually influenced by recall bias and poor methodology. While the study conducted a systematic review, additional sources were collected using an open-source strategy which might have been affected by selection bias of respondents.
2020	Lan et al.	Six Asian	690 locally	Observational	Number of cases	Workplace largely	A total of 103	The five	The exact

Table 2. Studies reporting outdoor SARS-CoV-2 transmission.

		regions: including Hong Kong, Japan, Singapore, Taiwan, Thailand, and Vietnam Between January 23, 2020 and March 14, 2020.	transmitted cases	study, extracted confirmed COVID-19 cases from governmental investigation reports. Only locally transmitted (non-imported) cases were included. Transmission period was extended to 40 days from primary case.	per occupation across country/area and stratified into early (first 10 days) and late (11-40th day) transmission periods.	outdoors	possible work-related cases were determined to be outdoors among a total of 690 local transmissions. Of workers that might be prevalently outdoors, 5% of cases were construction workers. Tour guides (5% of cases) might also be considered to have occurred partly outdoors.	occupation groups with the most cases were healthcare workers (22%), drivers and transport workers (18%), services and sales workers (18%), cleaning and domestic workers (9%) and public safety workers (7%).	outdoor/indoor makeup of the location of transmission was not described. This is in part due to the fact that the transmission source was not always known, and detailed occupational histories were also not always known. Also, none of the reports arose from systematic testing of high-risk occupations, rather from individual case reports, which might have been affected by biased and heterogenous reporting mechanisms from different regions.
2020	Szablewski et al.	Overnight camp in Georgia, USA. June 17-27 2020.	During June 17–20 the overnight camp held orientation for 138 trainees and 120 staff members; staff members remained for the first camp session, scheduled during June 21–27, and were joined by 363	Retrospective Case Investigation (MMWR)	Positive test result for SARS-CoV-2 (symptomatic and asymptomatic)	Camp attendees were cohorted by cabin and engaged in a variety of indoor and outdoor activities, including daily vigorous singing and cheering.	On June 24 a staff member tested positive to SARS-CoV-2. Test results were later available for 344 attendees; among these, 260 (76%) were positive. The percentage of transmission that	Median cabin attack rate was 50% among 28 cabins that had one or more cases (on average, each cabin housed 15 people). Attack rate was highest in the larger cabin, suggesting the	Attack rates are likely an underestimate because cases might have been missed among persons not tested or whose test results were not reported. Some cases may have

Table 2. Studies reporting outdoor SARS-CoV-2 transmission.

			campers and three senior staff members on June 21. Children and adults attended.				developed solely outdoors was not investigated.	main location of transmission was in the cabins.	resulted from transmission occurring before or after camp attendance. Lastly, exact details of outdoor activities versus indoor were not described.

Table 3. Studies reporting other outdoor respiratory virus transmission ordered by infection identified.										
Year	**Author**	**Virus**	**Location and Date**	**Sample Description**	**Design**	**Outcomes measured**	**Outdoor exposure**	**Outdoor findings**	**Indoor findings**	**Bias**
2017	Figueroa et al.	Respiratory disease outbreaks	United States, 2009-2014	18 mass gatherings in 8 states.	Data was collected on mass gathering related respiratory disease outcomes. 50 state health departments and 31 large local health departments were contacted via online assessment. 43 (53%) of 81 health jurisdictions responded.	Outbreak was defined as one or more cases of an infectious respiratory disease. Mass gathering (exposure) was defined as a planned or unplanned congregation of 1,000 or more persons in either an indoor or outdoor venue for a common purpose.	Mass gatherings were defined as indoors or indoor/outdoors.	All reported outbreaks occurred at multi-day mass gathering events. For Influenza A (H1N1) attack rates at two summer camps were of 1.4% and 4.8% respectively. Attack rate for a religious event was of 19.5%. At a sporting event in the spring, it was of 3.3% - but only included athletes. Attack rate of Inluenza A (H3) at another summer camp was of 0.02%.	At a professional conference in the winter, which was likely to be mostly indoors, attack rate was of 21.0%. Probable factors that affected attack rates were participant density and susceptibility, rather than gathering size alone. Use of non-pharmaceutical interventions (eg. handwashing, surface cleaning) might have been an additional factor.	Low response rate (around 50%) by state health departments, while there was no response from local health departments. There might be responded bias, given that departments which experienced mass gathering outbreaks might have been more willing to respond. Furthermore, the details of each mass gathering and their indoor/outdoor locations are not described.
2016	Rainey et al.	Respiratory disease outbreaks	United States, 2005-2014	21 published articles describing 72 mass gathering-related respiratory disease	Six medical, behavioral and social science literature databases were analyzed to extract relevant articles. NORS	Mass gatherings were defined as large events involving more than 1,000 persons in a specific	The authors did not specify outdoor vs indoor location of mass gathering.	Close social mixing and contact in communal housing/activities were associated with all other outbreaks identified. They	All reported outbreaks in summer camps had social contact and communal housing, none reported without	Search strategy might have not captured studies that did not use the word "outbreak", and might have missed any outbreak not captured by surveillance systems

Table 3. Studies reporting other outdoor respiratory virus transmission ordered by infection identified.

				outbreaks. 1,114 outbreaks reported to NORS (National Outbreaks Reporting System)	was also analyzed to estimate the frequency of mass gathering-related respiratory disease outbreaks.	location for a shared purpose. Definition of outbreak was deferred to the author's definition. Half of the reported outbreaks were related to a zoonotic source and were excluded. 38% of the outbreaks occurred at a variety of camps.		concluded that multiday mass gatherings with indoor residential overnight components can facilitate transmission.	a housing component.	(eg. smaller outbreaks, of diseases with longer incubation periods). Not much detail was shared on the indoor/outdoor locations and activities at the gatherings where outbreaks occurred.
2013	Botelho-Nevers et al.	Disease outbreaks (including respiratory disease)	"open air mass gatherings" worldwide, 1980-2012	9 published articles about respiratory infections at large, outdoor mass gatherings, festivals, or music festivals	Literature search using ProMed and MEDLINE database, with crossreferencing using search engines such as google and yahoo	Outbreaks in the setting of open-air gatherings.	Mass gatherings defined as "generally outdoors", but which may have onsite housing and food supply.	Four outbreaks of Influenza A (H1N1) and one of Influenza A and B were found. Overall, the estimated incidence of confirmed respiratory infections of influenza per 100,000 attendees ranged from 2 to 30. The discrepancy between sport events, which seem to have lower	No exclusively indoor events were included.	The infections related to large open air festivals may be under-reported, given difficulty in ascertaining exact location of transmission and sporadic surveillance systems. The search strategy of only using ProMed and MEDLINE might have limited the amounts of results that might otherwise be available on other reporting/surveillance agencies.

Table 3. Studies reporting other outdoor respiratory virus transmission ordered by infection identified.

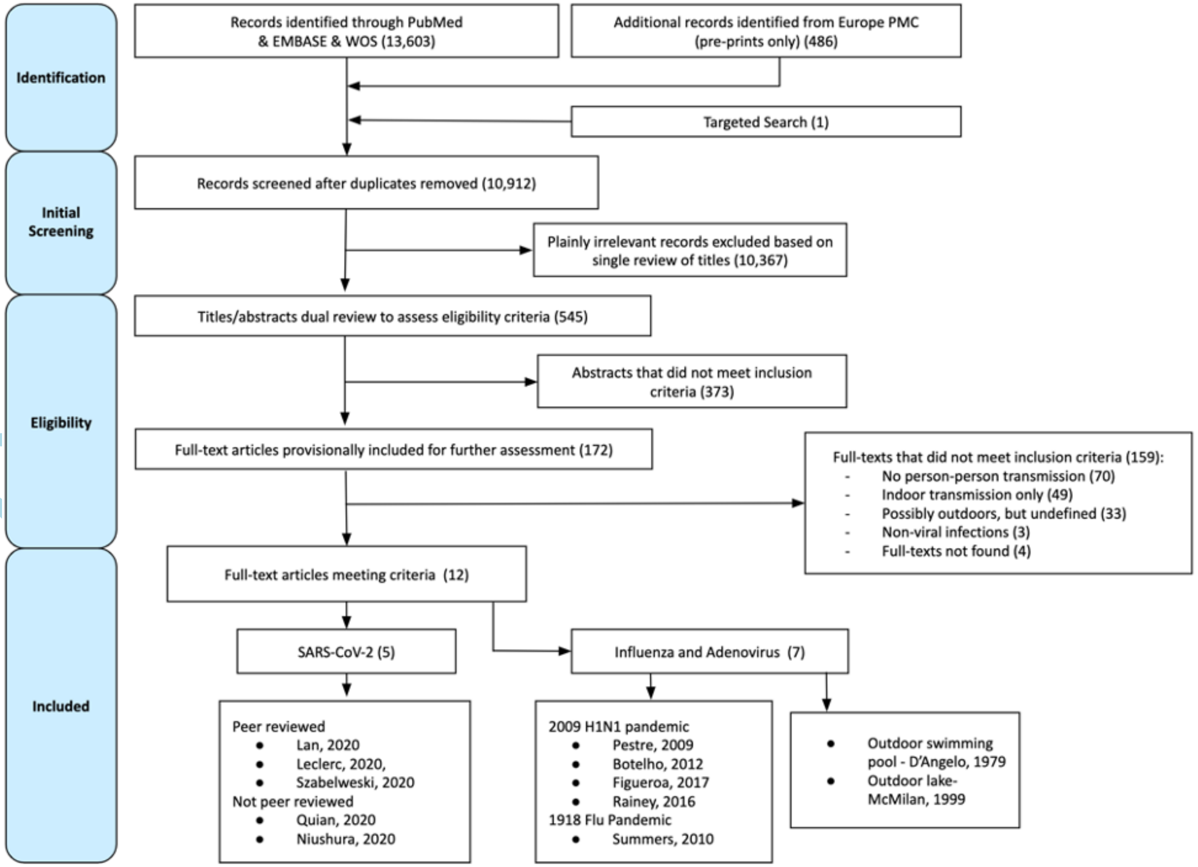
								incidence, and large scale open air festivals in terms of infectious diseases may also be the consequence of the relatively short duration of sports events which frequently last shorter than one day.		
2011	Pestre et al.	2009 H1N1 Influenza	Summer camp in France, August 2009	32 persons participated in the holiday camp. 29 of them traveled in the same train wagon.	Retrospective Case Investigation	Infection of H1N1 influenza.	Individuals who did not travel in the same train wagon.	The outbreak involved 21 children and 3 adults who had all travelled together in the same wagon. The three individuals that did not take the same train wagon and were immediately thereafter in contact with the 24 infected individuals at camp did not experience influenza symptoms.	Out of 29 individuals who took the same train wagon, 21 children and 3 adults experienced symptoms.	Conditions of outdoor versus indoor activities at camp were not described. Given this, the comparison between indoor (train wagon) and outdoor (camp) exposure assumes that a majority of time at camp, as compared to the train wagon, was outdoors. Measurement of cases might have been affected by timing of testing and/or presence of asymptomatic cases. Limitations were not discussed.
2010	Summers et al.	1918 Influenza	His Majesty's New Zealand Transport military troop ship in Sierra	1,217 persons onboard	Retrospective Historical Outbreak Analysis	Mortality	Sleeping in hammocks as opposed to cabins with bunks	Out of 1,217 persons onboard, over 1,000 suspected cases of influenza, 68 deaths. Mortality rate for persons that slept in	Mortality rate for persons that slept in cabins with bunks was of 39/267 (146.1 persons/1,000 population). The difference	Historical evidence used in this paper is subject to transcription and/or recording errors, lack of case definitions, and approximate estimates of case numbers. While it is

Table 3. Studies reporting other outdoor respiratory virus transmission ordered by infection identified.

			Leone, July 1918					hammocks outdoors was of 28/820 or of 34.1 persons/1,000 population.	between hammocks was significant (crude RR 4.28, 95% CI 2.69–6.81). Density did not seem to be a contributing factor.	hinted that hammocks were in higher ventilated zones as compared to cabins, the exact location of hammocks was not described.

Table 4. Outdoor conditions where COVID-19 was transmitted			
Setting	**Description of transmission**	**Purely outdoors?**	**Use of Non-Pharmaceutical Interventions***
Overnight summer camp [18]	Outbreak of 260 cases during an overnight camp in Georgia. Everyone was tested negative for COVID less than or equal to 12 days prior to coming to camp. While exact outdoor activities were not described, the overnight component suggests that the attack rate increased with length of time spent at the camp. This was shown by staff members, who were present at camp the longest, having the highest attack rate (56%). Attack rate associated with being adult, length of stay, and being in a cabin together. Median attack rate in the cabins: 50%, overall attack rate 44%.	No	Yes. They state the NPI was not effective. The non-pharmaceutical interventions they tried was cohorting of attendees by cabin (less than or equal to 26 persons), staggering of cohorts for use of communal spaces, physical distancing outside of cabin cohorts, and enhanced cleaning and disinfection, especially of shared equipment and spaces. Cloth masks were required for staff members. Evidently, these interventions were not effective at preventing a majority of cases.
Conversation in outdoor setting [14]	One outdoor transmission involving two cases in Shangqiu, Henan: a 27-year-old man had a conversation outdoors with an individual who had returned from Wuhan. No secondary or tertiary cases from this transmission were reported	Yes	Unknown
Outdoor construction sites [16,17]	Four outbreaks at outdoor construction sites in Singapore, involving a total of 95 cases [16] Five cases of construction workers in Singapore [17]. Details of exact location of transmission were not described. Details of how "indoors" versus outdoors unknown. However, in Leclerc et al. building sites were described as "outdoor" settings.	Unknown	Unknown
Jogging outdoors [16]	One transmission while jogging in Codogno, Italy (reported by local news media, cited in Leclerc et al. open source database)	Yes	Unknown
Outdoor park [16]	Twenty cases in an outdoor park in Münster, Germany (reported by local news media, cited in Leclerc et al. open source database). The members of the extended family, who had been living in different houses in the Angelmodde district of Munster, were suspected to have met often on a playground in the Osthuesheide district. The activites of the family were not described, but it was described as a repeated exposure over days.	Yes	Unknown
* Such as masks, physical distance, cohorting.			

Figure 1


Identification
Initial Screening
Eligibility
Included
Records identified through PubMed & EMBASE & WOS (13,603)
Additional records identified from Europe PMC (pre-prints only) (486)
Targeted Search (1)
Records screened after duplicates removed (10,912)
Plainly irrelevant records excluded based on single review of titles (10,367)
Titles/abstracts dual review to assess eligibility criteria (545)
Abstracts that did not meet inclusion criteria (373)
Full-text articles provisionally included for further assessment (172)
Full-texts that did not meet inclusion criteria (159):
- No person-person transmission (70)
- Indoor transmission only (49)
- Possibly outdoors, but undefined (33)
- Non-viral infections (3)
- Full-texts not found (4)
Full-text articles meeting criteria (12)
SARS-CoV-2 (5)
Influenza and Adenovirus (7)
Peer reviewed
• Lan, 2020
• Leclerc, 2020,
• Szabelweski, 2020
Not peer reviewed
• Quian, 2020
• Niushura, 2020
2009 H1N1 pandemic
• Pestre, 2009
• Botelho, 2012
• Figueroa, 2017
• Rainey, 2016
1918 Flu Pandemic
• Summers, 2010
• Outdoor swimming pool - D'Angelo, 1979
• Outdoor lake- McMilan, 1999