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PERSPECTIVES

# Transmission Potential of Human Monkeypox in Mass Gatherings

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Since May 2022, a large number of monkeypox cases have been reported in Europe, the United States, and other nonendemic settings. Taking into account the strict measures implemented due to the coronavirus disease 2019 pandemic and the desire of people to reclaim what is perceived as lost time, mass gatherings this summer were highly attended. Based on data for the secondary attack rate among unvaccinated contacts from endemic countries, we estimate that, on average, >1 secondary case is anticipated per infectious person if he/she has a high number of group contacts (>30) or >8 close contacts. Although the role of group contacts in mass gatherings is uncertain (less likely to involve physical contact, shorter duration), close contacts associated with the event (eg, intimate/sexual contact with other attendees) might be the amplifying event. Enforcing awareness, early recognition, and engaging affected populations in the monkeypox response are important to control transmission.

**Keywords.** monkeypox; basic reproduction number; mass gathering; secondary attack rate.

On 23 July 2022, monkeypox was declared a Public Health Emergency of International Concern (PHEIC) by the Director-General Tedros Adhanom Ghebreyesus of the World Health Organization [1]. In total, 49 531 monkeypox cases have been reported in nonendemic settings in 2022, as of August 30 [2]. To date, most cases have been identified, but not exclusively, in gay, bisexual, and other men who have sex with men (MSM), and transmission has occurred predominantly through sexual activity [3]. In Europe, several of the first cases were associated with saunas and fetish festivals, whereby individuals were exposed to the virus through close contact [4,5]. It is known that social and mass gatherings constitute high-risk settings for the transmission of infectious diseases, especially in crowded venues, as there is attendance of a large number of people, in close proximity with prolonged and frequent interaction between people [6,7]. Furthermore, attendance by persons traveling from other countries can further facilitate the introduction and spread of novel pathogens. Taking into account the strict measures implemented in many countries for >2 years due to the coronavirus disease 2019 (COVID-19) pandemic and the desire of people, including younger persons, to socialize, celebrate, and reclaim what is perceived as lost time, it was anticipated that such gatherings would be highly attended. From this perspective, we aim to assess the potential for monkeypox transmission under various scenarios concerning number of contacts and discuss the implications for transmission in venues and settings where conditions are conducive to amplifying spread.

## Mass Gatherings and Social Contacts

During the summer, social/mass gatherings are commonplace, including music festivals that attract thousands of people, such as Glastonbury in the United Kingdom (~200 000 people/day), the Zurich Street Parade in Switzerland (techno party with ~850 000 people in 2019), and Summerfest in Wisconsin (~850 000 people attend over several days) [8,9]. After COVID-19-related restrictions imposed in the 2 past years leading to cancellation or to attendance restrictions, events this summer were anticipated [10]. Apart from music festivals, other events have been organized such as parties in popular summer travel destinations (eg, Ibiza in Spain and Mykonos in Greece).

The number of contacts in mass gatherings cannot be easily predicted and ascertained. From social contact surveys, the mean number of contacts on a Saturday in Germany (including group contacts) was 19.5 [11], whereas the average size of group contacts in the United Kingdom was 20.3, with one-fourth of them being physical [12]. However, estimates on the number, duration, and type of contacts obtained from such surveys cannot be reliably extended to the setting of mass gatherings where thousands of people congregate for prolonged periods. Other approaches are necessary. For example, social mixing patterns at an event

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have been estimated using video analysis technology [13]. An experiment to measure direct contacts was performed in an indoors mass gathering (seated concert) where contact tracing devices were handed out to ~1100 attendees [14]. In this concert, there were contacts with an average of 8.9 and 14.1 people lasting for more than 15 and 5 minutes, respectively.

Apart from the fact that crowding during these events is likely to lead to close, prolonged contact between people and to create the conditions for monkeypox transmission, another important point to consider is that some mass gatherings may be associated with social and behavioral risk factors, such as excessive consumption of alcohol and/or unsafe sexual practices [6,15,16]. It has been theorized that sharing a social identity in mass gatherings lowers health risk perceptions [17]. For example, people experiencing a shared social identity may become less concerned with physical proximity, and the risk from casual, condomless sex tends to be underestimated by group members. Furthermore, according to data collected through the European Men-Who-Have-Sex-With-Men Internet Survey (EMIS), 25% of MSM respondents reported having sex while traveling abroad in the previous 12 months with a person not resident in the respondent's country of residence [18]. These factors highlight the difficulty of quantifying the risk for monkeypox transmission in mass gatherings as the nature and number of high-risk contacts are highly uncertain.

#### Estimates of Human-to-Human Transmissibility of Monkeypox Virus

The increase in the number of reported monkeypox cases in endemic countries over time, in parallel with the declining vaccination coverage for smallpox [19] and the current outbreaks in nonendemic countries declared by the World Health Organization (WHO) as PHEICs, confirm the transmission potential from human to human. The basic reproduction number ($R_0$) denotes the average number of secondary cases infected by each primary case in a fully susceptible population and in the absence of preventive measures. The available data on $R_0$ for monkeypox are limited and not contemporary [20]. In fact, estimates were derived from endemic countries in past years where a large proportion of the population was vaccinated against smallpox. When this was taken into account in a recent paper, the $R_0$ in a completely susceptible population was estimated to be around 2 [21]. There are, however, available estimates of the secondary attack rates (SARs)—separately for household and nonhousehold as well as for vaccinated and unvaccinated contacts—that can be used to estimate $R_0$ [22–25]. More specifically, if transmission is stratified by contacts within and outside of the household, then $R_0 = SAR_1 \cdot N_1 + SAR_2 \cdot N_2$ (Equation 1), where $SAR_1$, $SAR_2$ are the secondary attack rates and $N_1$, $N_2$ are the numbers of at-risk contacts made within the household and wider community, respectively [26,27].

#### $R_0$ for Monkeypox in the Setting of Social/Mass Gatherings

We attempted to explore the transmission potential of human monkeypox in mass gatherings under various scenarios for the number of close and other (group) contacts. We assumed that an infectious person attending such an event will have 2–10 close contacts (eg, friends, sexual partners), as well as contacts with other attendees (ranging from 5 to 50). We obtained $R_0$ using Equation 1, where we applied available estimates of the secondary attack rate for unvaccinated contacts [22]. More specifically, we used the household and nonhousehold SAR estimates for close contacts and for contacts with other attendees, respectively. To account for the uncertainty in SAR, we performed simulations where we obtained SAR from a normal distribution using the estimated mean and 95% CI from a meta-analysis (estimate [95% CI]: 7.57 [0–15.17] for unvaccinated close contacts and 2.69 [0–6.17] for unvaccinated other contacts) [22]. In each scenario for the number of contacts, the mean $R_0$ and 2.5th and 97.5th percentiles were obtained through 5000 simulations.

Based on the simulations (Figure 1), the mean $R_0$ could reach up to 2.1 in the case of a high number of close and other contacts. The $R_0$ could exceed 1 if the infectious person has contacts with more than ~30 persons even if he/she has close contacts with only 2–3 persons. Similarly, a high number of close contacts (8–10 contacts) could lead to >1 secondary case even if the number of other contacts is relatively small (<15).

## DISCUSSION

There is potential for increased transmission of human monkeypox in nonendemic areas during social/mass gatherings. However, our estimates should be interpreted with caution, taking into account several limitations. First, we assumed a totally susceptible population given that smallpox vaccination ended in the early 1970s in Europe and the United States and that mass gatherings, such as concerts, are mainly attended by younger people. Second, the secondary attack rates we have used were obtained from data collected several years ago in endemic countries; other factors may have contributed to increased transmission in these settings besides lack of immunity, like poor hygiene and crowded living quarters. Third, the predominant transmission routes in endemic and nonendemic settings are different. In endemic countries, risk factors for secondary transmission include close contact by sharing a bed or playing (for children) with a case, and transmission occurs in the general population [28]; sexual transmission of monkeypox has been described, but infrequently. In the recent outbreak in nonendemic settings, transmission occurred predominantly through sexual activity among MSM [3]. Thus, multiple sexual contacts or chemsex parties within the setting of mass gathering events may accelerate transmission [29] and result in a higher reproduction number. Fourth,

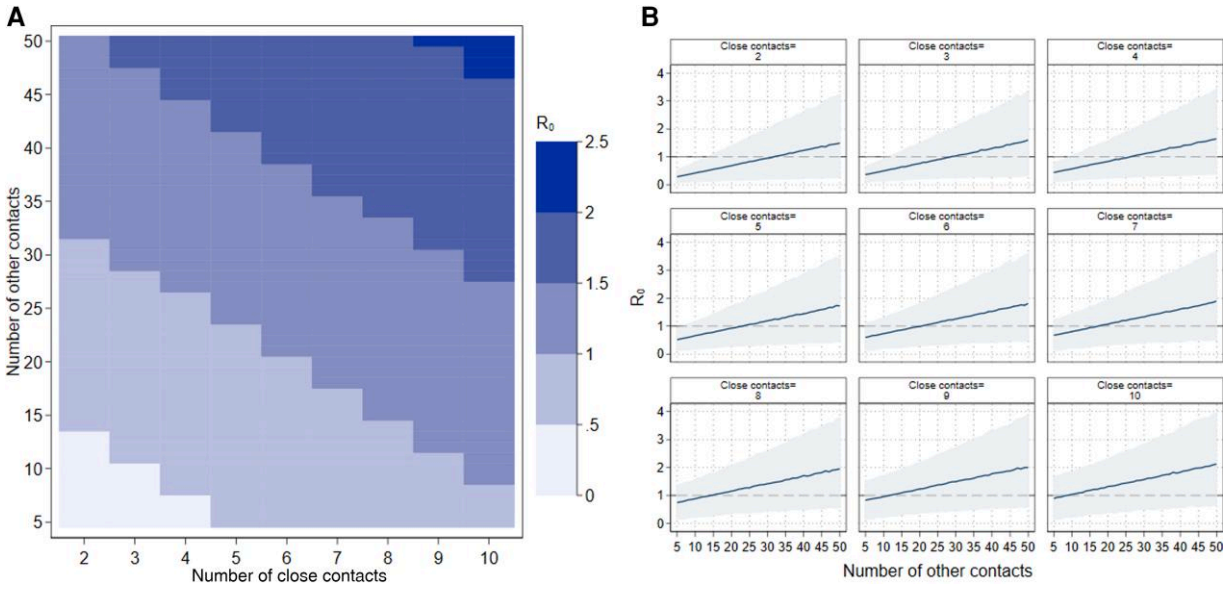


**Figure 1.** Basic reproduction number ($R_0$) estimated under various scenarios for the number of close and other (group) contacts in a mass gathering. Mean and 95% credible intervals were obtained through 5000 simulations with secondary attack rates for unvaccinated contacts obtained from Beer and Rao [22]. *A*, Heatmap of the mean $R_0$. *B*, Mean (thick lines) and 95% credible intervals (shaded areas) of $R_0$. The dashed line indicates the threshold of $R_0 = 1$. Subgraphs correspond to the respective number of close contacts.

the secondary attack rate is the probability that a case infects a contact over his or her infectious period, whereas mass gatherings may have a duration of a few hours up to a few days. However, the SAR estimate for nonhousehold contacts that we have used to assess transmission among nonclose contacts in a mass gathering may be still appropriate as nonhousehold contacts do not last over the whole infectious period and could even be a one-time event.

The number of effective contacts, that is, contacts sufficient to lead to monkeypox transmission between an infectious and a susceptible individual in the setting of mass gatherings, is uncertain. For instance, in concerts with thousands of attendees, it is anticipated that the number of contacts will be high. However, compared with individual contacts, group contacts are less likely to be physical. In addition, there is a saturation of contact duration for individuals with large numbers of contacts [12]. As a result, the role of these encounters in transmission may not be important. Close contacts associated with the event (but not taking place during the event, such as intimate or sexual contact with other attendees) could be the amplifying event. In our simulations, 8–10 close contacts could lead to >1 secondary case, on average, per index case even if the number of other contacts is relatively small. Our simulation results are in line with estimates derived from data on the number of diagnosed monkeypox cases in Spain, Portugal, and the United Kingdom that place the value of $R_0$ between 1.4 and 1.8 [1], as well as from 6 countries with increasing confirmed monkeypox cases in 2022, where the estimated effective reproduction number was found to lie within the range of 1.02 to 1.55 [30].

## CONCLUSIONS

Our results confirm the potential for monkeypox transmission under various scenarios concerning the number of contacts. In view of mass gatherings and relaxation after 2 years of social restrictions, increased awareness and early recognition are important to control transmission and stop the spread. Gatherings are opportunities for information outreach, risk communication, and community engagement activities [7]. The WHO recently released a tool with practical information on monkeypox for people planning to attend large gatherings, events, or parties [31]. Public health authorities, governments, and other stakeholders should make every concerted effort to ensure that no population affected by monkeypox is stigmatized. Instead, the people most affected in the current outbreak, MSM, should be actively engaged in the monkeypox response, including in the critical area of risk communication and community engagement, which is at the core of an effective public health response [32].


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***Author contributions.*** All authors fulfilled the ICJME authorship criteria. V.S. prepared the first draft and performed the simulations. S.T. and

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***Ethical approval.*** No ethical approval was required as the analysis was performed using estimates from the literature.

***Patient consent.*** The study does not include factors necessitating patient consent.

## References


1. World Health Organization. Second meeting of the International Health Regulations (2005) (IHR) Emergency Committee regarding the multi-country outbreak of monkeypox. **2022**. Available at: https://www.who.int/news/item/23-07-2022-second-meeting-of-the-international-health-regulations-(2005)-(ihr)-emergency-committee-regarding-the-multi-country-outbreak-of-monkeypox. Accessed August 31, 2022.
2. CDC. 2022 Monkeypox Outbreak Global Map. Available at: https://www.cdc.gov/poxvirus/monkeypox/response/2022/world-map.html. Accessed August 31, 2022.
3. Thornhill JP, Barkati S, Walmsley S, et al. Monkeypox virus infection in humans across 16 countries—April-June 2022. N Engl J Med **2022**; 387:679–91.
4. Zumla A, Valdoleiros SR, Haider N, et al. Monkeypox outbreaks outside endemic regions: scientific and social priorities. Lancet Infect Dis **2022**; 22:929–31.
5. Aidsmap. Monkeypox is spreading among gay men worldwide. **2022**. Available at: https://www.aidsmap.com/news/may-2022/monkeypox-spreading-among-gay-men-worldwide. Accessed August 31, 2022
6. Abubakar I, Gautret P, Brunette GW, et al. Global perspectives for prevention of infectious diseases associated with mass gatherings. Lancet Infect Dis **2012**; 12:66–74.
7. World Health Organization. Monkeypox & mass gatherings. Recommendations for mass gatherings during a monkeypox outbreak. **2022**. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiF6Kjr9_j6AhXkXvEDHSXECIMQFnoECAkQAQ&url=https%3A%2F%2Fcdn.who.int%2Fmedia%2Fdocs%2Fdefault-source%2Fepi-win%2Fupdate78_monkeypox-mass-gatherings.pdf%3Fsfvrsn%3Ddfc9ee5a_1%26download%3Dtrue&usg=AOvVaw3QenKKikZczx7R0C7GqyLo. Accessed August 31, 2022.
8. BBC News. Music festivals: What's the world's biggest? *BBC*. July 4, **2018**. Available at: https://www.bbc.com/news/world-44697302. Accessed August 31, 2022.
9. Hundreds of thousands flocked to Zurich on Saturday for the Zurich Street Parade. *Swissinfo.ch*. August 9, **2019**. Available at: https://www.swissinfo.ch/eng/dancing-in-the-streets_the-zuerich-street-parade/45144340. Accessed August 31, 2022.
10. Jedicke P. Music festival season kicks off in Europe. *Deutsche Welle*. June 3, **2022**. Available at: https://www.dw.com/en/music-festival-season-kicks-off-in-europe/a-62024454. Accessed August 31, 2022.
11. Tomori DV, Rubsamen N, Berger T, et al. Individual social contact data and population mobility data as early markers of SARS-CoV-2 transmission dynamics during the first wave in Germany—an analysis based on the COVIMOD study. BMC Med **2021**; 19:271.
12. Brooks-Pollock E, Read JM, House T, Medley GF, Keeling MJ, Danon L. The population attributable fraction of cases due to gatherings and groups with relevance to COVID-19 mitigation strategies. Philos Trans R Soc Lond B Biol Sci **2021**; 376:20200273.
13. Rainey JJ, Koch DB, Chen YH, Yuan J, Cheriyadat A. Using video-analysis technology to estimate social mixing and simulate influenza transmission at a mass gathering. Epidemics **2021**; 36:100466.
14. Moritz S, Gottschick C, Horn J, et al. The risk of indoor sports and culture events for the transmission of COVID-19. Nat Commun **2021**; 12:5096.
15. Cruwys T, Saeri AK, Radke HRM, Walter ZC, Crimston CR, Ferris LJ. Risk and protective factors for mental health at a youth mass gathering. Eur Child Adolesc Psychiatry **2019**; 28:211–22.
16. Lim MS, Hellard ME, Aitken CK, Hocking JS. Sexual-risk behaviour, self-perceived risk and knowledge of sexually transmissible infections among young Australians attending a music festival. Sex Health **2007**; 4:51–6.
17. Khazaie DH, Khan SS. Shared social identification in mass gatherings lowers health risk perceptions via lowered disgust. Br J Soc Psychol **2020**; 59:839–56.
18. European Centre for Disease Prevention and Control. Rapid risk assessment: potential public health risks related to communicable diseases at the WorldPride festival in Madrid, 23 June–2 July 2017, 5 May 2017.Stockholm: ECDC; **2017**. Available at: https://www.ecdc.europa.eu/sites/default/files/documents/RRA-Mass%20gathering-WorldPride-Spain-5-May-2017.pdf. Accessed August 31, 2022.
19. Rimoin AW, Mulembakani PM, Johnston SC, et al. Major increase in human monkeypox incidence 30 years after smallpox vaccination campaigns cease in the Democratic Republic of Congo. Proc Natl Acad Sci U S A **2010**; 107:16262–7.
20. Fine PE, Jezek Z, Grab B, Dixon H. The transmission potential of monkeypox virus in human populations. Int J Epidemiol **1988**; 17:643–50.
21. Grant R, Nguyen LL, Breban R. Modelling human-to-human transmission of monkeypox. Bull World Health Organ **2020**; 98:638–40.
22. Beer EM, Rao VB. A systematic review of the epidemiology of human monkeypox outbreaks and implications for outbreak strategy. PLoS Negl Trop Dis **2019**; 13:e0007791.
23. Jezek Z, Grab B, Szczeniowski MV, Paluku KM, Mutombo M. Human monkeypox: secondary attack rates. Bull World Health Organ **1988**; 66:465–70.
24. Hutin YJ, Williams RJ, Malfait P, et al. Outbreak of human monkeypox, Democratic Republic of Congo, 1996 to 1997. Emerg Infect Dis **2001**; 7:434–8.
25. Breman JG, Kalisa R, Steniowski MV, Zanotto E, Gromyko AI, Arita I. Human monkeypox, 1970–79. Bull World Health Organ **1980**; 58:165–82.
26. Yang Y, Halloran ME, Sugimoto JD, Longini IM, Jr. Detecting human-to-human transmission of avian influenza A (H5N1). Emerg Infect Dis **2007**; 13:1348–53.
27. Liu Y, Eggo RM, Kucharski AJ. Secondary attack rate and superspreading events for SARS-CoV-2. Lancet **2020**; 395:e47.
28. Heymann DL, Szczeniowski M, Esteves K. Re-emergence of monkeypox in Africa: a review of the past six years. Br Med Bull **1998**; 54:693–702.
29. European Centre for Disease Prevention and Control. Monkeypox multi-country outbreak—23 May 2022. 23 May 2022. ECDC: Stockholm; **2022**. Available at: https://www.ecdc.europa.eu/sites/default/files/documents/Monkeypox-multi-country-outbreak.pdf. Accessed August 31, 2022
30. Du Z, Shao Z, Bai Y, et al. Reproduction number of monkeypox in the early stage of the 2022 multi-country outbreak. J Travel Med. **2022**:taac099. doi: 10.1093/jtm/taac099.
31. World Health Organization. New mobile friendly web tool with interactive dashboard gives individuals the information they need on monkeypox in advance of attending gatherings. **2022**. Available at: https://www.who.int/europe/news/item/23-08-2022-new-mobile-friendly-web-tool-with-interactive-dashboard-gives-individuals-the-information-they-need-on-monkeypox-in-advance-of-attending-gatherings. Accessed September 2, 2022.
32. European Centre for Disease Prevention and Control/World Health Organization Regional Office for Europe. Interim advice on risk communication and community engagement during the monkeypox outbreak in Europe. **2022**. Available at: https://www.ecdc.europa.eu/en/publications-data/interim-advice-risk-communication-and-community-engagement-during-monkeypox. Accessed August 31, 2022.