Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Letter to the Editor

Risk at mass-gathering events and the usefulness of complementary events during COVID-19 pandemic

Dear editor,

Case clusters of COVID-19 have been reported in large mass-gathering events as well as parties and activities where a relatively small number of people were involved [1]. As reported in this journal, asymptomatic individuals can be a primary case of such clusters [2,3]. Because interventions on the generation of case clusters are believed to be a key to preventing the spread of COVID-19 [4], it would be helpful to be aware of the probability that infectious people will be attending an event.

Complementary event to calculate the risk at mass-gathering events

Let us consider an example. A city has a population of 100,000. Twenty people were tested positive for SARS-CoV-2 every day on average. Therefore, the daily incidence rate is $20/100{,}000 = 0.0002$. If a big event with 1000 attendees will convene in the city tomorrow, what is the probability that there will be infectious people at the event, and how many infectious people will there be?

We should consider a complementary event in the mathematical sense for that kind of inference. When you would like to know the probability that there will be at least one infectious person attending the event, you should first calculate the probability that there will be NO infectious people. Let X be the true prevalence of infectious people in the population. X can be interpreted as the probability that one individual is infectious. Then, 1 – X is the probability that one individual is NOT infectious. To calculate the probability that all 1000 attendees are NOT infectious, 1 – X should be multiplied 1000 times: $(1 - X)^{1,000}$. Finally, we know the probability that there will be at least one infectious person by using a concept of a complementary event: $1 - (1 - X)^{1,000}$. Furthermore, the expected number of infectious people is $1000 \times X$.

Statistical model using epidemiological information about COVID-19

Let us now add a twist to the statistics using epidemiological information about COVID-19. The number of reported cases is not equal to the actual number of infected individuals, because there is a population of infected people who are not tested and therefore are not detected. Let's assume that 60% of infected persons are not detected. By factoring in the estimated 60% of undetected infected individuals, the actual daily incidence is $0.0002 / (1–60\%) = 0.0005$. Studies indicated that the fraction of infected people reported as COVID-19 cases could be less than 10% in some areas [5,6].

Infected individuals can be infectious for ~10 days [7,8]. After an individual tests positive, they are required to enter quarantine or isolation so that they do not transmit the disease. If the positive case is detected 7 days after infection, which approximately corresponds to 2–3 days after illness onset, then the individual is infectious for only 7 days of the 10-day infectious period in the communities. The prevalence of infectious individuals can be described as follows: $0.0005 \times 60\% \times 10 = 0.003$ undetected plus $0.0002 \times 7 = 0.0014$ later-detected. In sum, it is $0.003 + 0.0014 = 0.0044$.

A published study estimated that 36% of infections result in asymptomatic individuals [9]. Although viral transmission from asymptomatic individuals contributes to the disease spread, the relative risk of the transmission from asymptomatic individuals is 35% compared with that of symptomatic people [10]. We roughly interpret the finding as meaning that only 35% of asymptomatic people are infectious. Then, the prevalence of infectious peoples is as follows: $0.0044 \times (1–36\%) = 0.002816$ symptomatic and $0.0044 \times 36\% \times 35\% = 0.0005544$ asymptomatic. The sum of the two is $0.002816 + 0.0005544 = 0.0033704$. Finally, applying the probability that there will be at least one infectious individual at the event to a concept of a complementary event is $1 - (1 - 0.0033704)^{1,000} = \sim 0.966$ (96.6%). The expected number of infectious people is $1000 \times 0.0033704 = \sim 3$.

Screening for the presence of symptoms at events

The attendance of symptomatic people at the event can be prevented by conducting a questionnaire about the presence of symptoms and implementing fever screens. Now, let us assume that we can stop all symptomatic people from attending the event. Still, asymptomatic and presymptomatic infectious people might be attending the event. Presymptomatic people are as infectious as individuals who have already developed symptoms for the same length of period [7]. In other words, the ratio of presymptomatic infectious people and symptomatic infectious people is 1:1 (i.e., 1/2). Therefore, the prevalence of infectious people among attendees is $0.0044 \times (1–36\%) \times 1/2 = 0.001408$ presymptomatic and $0.0044 \times 36\% \times 35\% = 0.0005544$ asymptomatic. The sum of the two is $0.001408 + 0.0005544 = 0.0019624$. In this case, the probability that there will be at least one infectious individual attending the event can be expressed as $1 - (1 - 0.0019624)^{1,000} = \sim 0.860$ (86.0%). The expected number of infectious people is $1000 \times 0.0019624 = \sim 2$.

Discussion

The probability we deduced is not a decisive value. The calculations were made with a lot of uncertain assumptions. For example, it is virtually impossible to know in a real-time way the proportion of infected individuals who are undetected. Besides, we as-

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sume the same prevalence of infectious people between the entire population and event attendees, which is unrealistic.

Even though such limitations exist, we believe that using a concept of a complementary event (in the mathematical sense), with a simplified assumption, is useful for grasping the risk at mass-gathering events. We have also developed an online tool that can calculate the probability of infectious people being present at an event, which can be adjusted by the user to consider certain parameters: [https://yukifuruse.shinyapps.io/covid_eventrisk_en/].

The model can be used to decide if a certain event should convene during the COVID-19 epidemic. If the risk is high but an event cannot be cancelled, we would like to encourage people to take an alternative approach that switches physical gatherings to an online meeting, changes the venue from indoors to outdoors, or reduces the number of participants. Such complementary events (in the normal sense) can effectively reduce the risk of disease transmission.

Declaration of Competing Interest

None

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Yuki Furuse
Institute for Frontier Life and Medical Sciences, Kyoto University, Kyoto, Japan
E-mail address: furusey.kyoto@gmail.com