The Population Attributable Fraction (PAF) of cases due to gatherings and groups with relevance to COVID-19 mitigation strategies

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Summary

Background

Many countries have banned groups and gatherings as part of their response to the pandemic caused by the coronavirus, SARS-CoV-2. Although there are outbreak reports involving mass gatherings, the contribution to overall transmission is unknown.

Methods

We used data from a survey of social contact behaviour that specifically asked about contact with groups to estimate the Population Attributable Fraction (PAF) due to groups as the relative change in the Basic Reproduction Number when groups are prevented.

Findings

We estimate that PAF due to groups of 50+ people is 2.2% (95%CI 1.1%, 3.6%); the PAF due to groups of 20+ people is 6.4% (5.0%, 8.0%); the PAF due to groups of 10+ is 11.3% (9.9%, 13.0%)

Interpretation

Large groups of individuals have a small epidemiological impact; small and medium sized groups between 10 and 50 people have a larger impact on an epidemic.

Funding

The funders had no role in the design of this study.

INTRODUCTION

Preventing social contacts and mass gatherings has been used worldwide in the response to reduce transmission communicable diseases, including to reduce transmission of the coronavirus, SARS-CoV-2. As of March 2020, As of March 2020, multiple countries have banned all gatherings of 1,000 people or more; with some countries such as the Czech Republic and the USA banning much smaller groups.

Given knowledge of transmission mechanisms, bringing together large numbers of people into the same space should prove conducive for the spread of close-contact infectious diseases. Indeed, mass gatherings have been associated with outbreaks of communicable diseases such as measles[1], influenza[2] and meningitis[3]. And public health agencies, including the World Health Organization (WHO), have specific guidance for preventing disease outbreaks at mass gatherings[4]. Factors such as age of participant[1], zoonotic transmission and presence of animals[5], crowding[6,7], lack of sanitation[7], location and event duration[6] are associated with the reporting of mass gathering-related outbreaks.

Despite the evidence of the importance of mass gatherings for disease transmission from intuition and individual outbreaks, the population-level impact of different mass gathering policies has not been established. While systematic reviews have identified outbreak reports involving mass gatherings[5,6], the overall impact of mass gatherings could not be quantitatively assessed. A detailed modelling study of disease transmission in the state of Georgia, USA, found that in extreme scenarios when 25% of the population participated in a 2-day long gathering shortly before the epidemic peak, peak prevalence could increase by up to 10%[8]. More realistic scenarios resulted in minimal population-level changes[8].

Here, we use representative data on individuals' daily social contacts, including group contacts, to estimate the Population Attributable Fraction (PAF) due to mass gatherings and large numbers of contacts.

METHODS

Social contact data

The Social Contact Survey (SCS) [9,10] collected data on social contacts from 5,388 participants between 2009 and 2010 in the UK. Participants were asked to enumerate other people with whom they had had contact over the course of a single day. Contacts were defined as those with whom participants had a face-to-face conversation within 3 metres and/or physically touched skin-on-skin. Participants were able report individual contacts and up to five groups of contacts, for instance church groups, weddings, large work functions or multiple contacts at work. The 'groups' question was designed to aid participants in reporting multiple similar contacts. Group contacts were defined in the same way as individual contacts, i.e. if a person attended a concert with 1,000 people, but only spoke to 5 people, the number of recorded group contacts would be 5. Participants were asked whether members of the group knew each other.

As well as the number of contacts, participants were asked to estimate the length of time spent with each contact or group of contacts as either: less than 10 minutes, 11-30 minutes, 31-60 minutes or over 60 minutes.

The SCS data are available to download at http://wrap.warwick.ac.uk/54273/.

Reproduction Numbers and Population Attributable Fraction

The Population Attributable Fraction (PAF) is a quantity borrowed from non-communicable disease epidemiology. The PAF due with a risk factor is the percentage of disease burden or mortality that can be attributed to the presence of that increased risk. In previous work, we demonstrated that for infectious diseases, the PAF can be estimated as the percentage change in the Basic Reproduction Number (average number of secondary cases per infectious case in an otherwise susceptible population[11]) in the absence of the risk factor[12].

Here, we treat participation in a group as the risk factor and calculate the Basic Reproduction Number with and without groups of various sizes. For each participant, we use their k contact reports to calculate their individual Basic Reproduction Number, R_0. We assumed that R_0 is proportional to the number of individuals reported in the contact, n_i, ($n_i = 1$ for single contacts, $n_i > 1$ for groups) multiplied by the duration of each contact, d_i:

$$R_0 \propto \sum_{i=1}^{k} n_i d_i$$

The duration of each contact is taken as the mid-point of each time interval, i.e. 5 minutes, 20 minutes, 45 minutes and 6 hours, as recorded by the participant. For group contacts with more than 20 individuals, we observe a saturation of contact duration, therefore we divide the contact duration by the number of individuals in the group. 95% Confidence Intervals in R_0 were calculated using bootstrapping.

We calculated the PAF for groups of size G or greater is calculated as the percentage change in the Basic Reproduction Number:

$$PAF_G = 1 - R_0(without\ groups \geq G)/R_0(with\ groups).$$

We investigate the PAF for groups of greater than 10, and up to groups greater than 100, in increments of 10. We investigated differences between groups that knew each other and groups that did not know each other.

RESULTS

Impact of groups on numbers of contacts per person

48,001 unique contacts were reported by 5,388 participants. Of those, 42,945 (89%) were individual contacts and 5,056 groups were reported (accounting for 11% of reported contacts). The median and mean number of contacts per person was 11.5 and 27.0, range 1 to 3,011.

2,427 (45%) of participants reported group contacts. The majority of groups reported (3,860; 76%) were groups of people who knew each other. 2,979 (59%) groups had 10 or fewer members; the median and mean reported group size was 9 and 20.3 individuals respectively.

Restricting contacts to groups of size 50 or less, reduces the median and mean number of individual contacts per person to 11.0 and 18.8; restricting contact to groups of size 20 or less, reduces the median and mean number of contacts per person to 10.0 and 14.1; restricting contacts to groups of size 10 or less, reduces the median and mean number of contacts per person to 9 and 11.0. Figure 1 shows the degree distribution (number of contacts) per person with and without contacts associated with groups of size greater than 10.

Population Attributable Fraction (PAF)

The PAF due to groups decreased with increasing group size. For the largest groups with more than 100 individuals the PAF_{100} is estimated at 0.8% (0.3%, 1.7%). The PAF_{50} is estimated at 2.2% (95% Confidence Interval of the mean: 1.1%, 3.6%); the PAF_{20} is 6.4% (5.0%, 8.0%); the PAF_{10} is 11.4% (9.9%, 13.0%) (figure 2).

The pattern of decreasing PAF with increasing group size is seen for both groups of individuals who are known to each other and groups of individuals who are unknown to each other. The PAF due to groups of 10+ known to each other is estimated at 8.4% (7.4%, 9.4%) and due to groups of 50+ known to each other is estimated at 0.8% (0.5%, 1.3%). The remaining contribution to R_0 is due to contact with individuals.

The low estimated impact of large groups on R_0 is due to the relative frequency with which they are reported in the Social Contact Survey. These results highlight the relative importance of medium-size groups of between 10 and 20 individuals.

DISCUSSION

In this paper, we analysed social contact data in the context of infectious disease transmission and gatherings. Our findings suggest that large groups of individuals have a relatively small impact on an epidemic. This is due to the relative rarity of large-scale gatherings and the sub-linear scaling between number of contacts and infectivity.

The Social Contact Survey (SCS) is one of a number of social contact surveys that have been conducted to quantify the impact of social mixing on disease transmission[13–17]. The SCS specifically asked about groups of similar contacts. These groups are not necessarily public or mass gatherings, and represented groups that both knew each other and those that did not. The SCS asked about contacts on a single day, therefore did not capture multi-day events; simulation studies have shown that prolonged mass gatherings were necessary to alter the course of an epidemic[8]. Our analysis was based on social contact data collected between 2009 and 2010; contact patterns may have altered in the past decade. We also did not account for individuals changing their behaviour if group activities were cancelled.

In the context of COVID-19 mitigation, this analysis considered one aspect of gatherings: the impact on an epidemic. However, there may be other valid reasons for preventing mass events, such as policing and managing resources. Our analysis implicitly assumes that infection is already present in the population as is the case for COVID-19; for other diseases, mass gatherings can be associated with increased global travel which can bring new strains into an area or result in out-of-season outbreaks, which were also not captured here.

Our findings illustrate the difficult choices that are necessary to limit COVID-19 spread. Meetings of large groups of more than 100 individuals are relatively infrequent, and their prohibition may have a limited impact on the epidemic. More epidemiologically relevant are groups of 10 to 20 people, as they occur more frequently and could potentially have a larger impact on transmission; they may also involve inter-generational family groups.
This analysis was designed to aid policy-making and should be considered against alternative control strategies so that the most effective measures can be implemented in the long term.

Declaration of Interests
None

Funding source
EBP was partly supported by the National Institute for Health Research Health Protection Research Unit (NIHR HPRU) in Evaluation of Interventions. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health. The NIHR had no role in writing the manuscript or the decision to publish.

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Figures

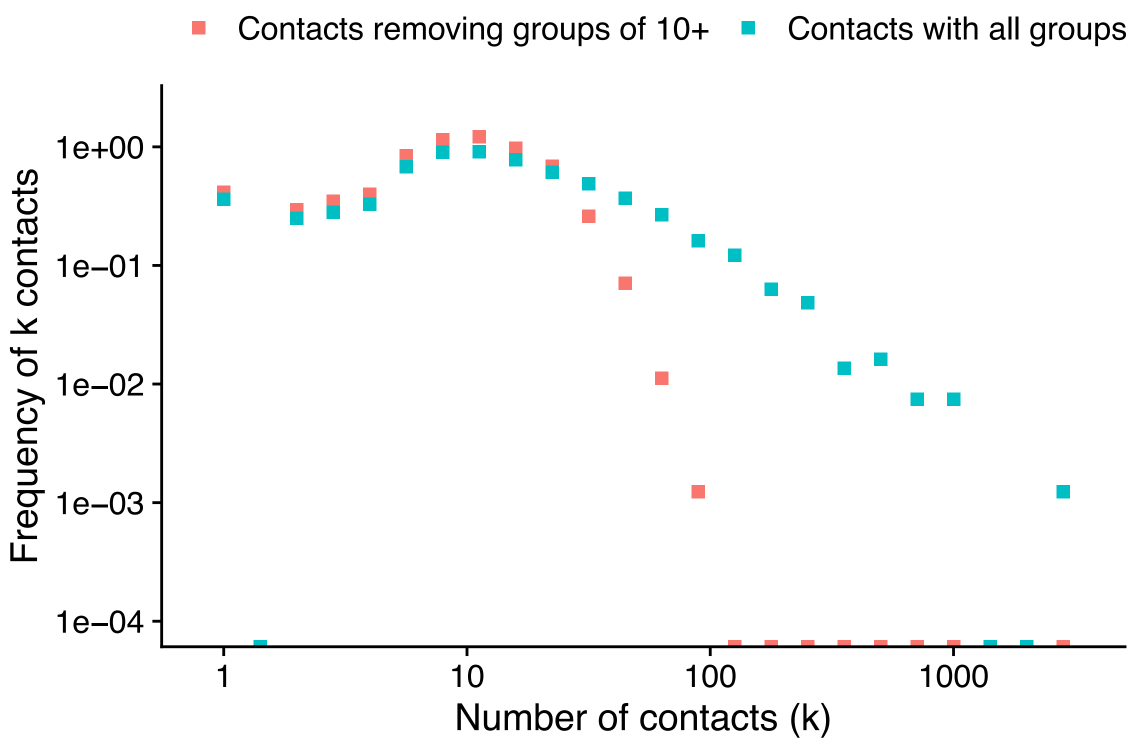

Figure 1: The number of social contacts per person with and without groups of 10+.

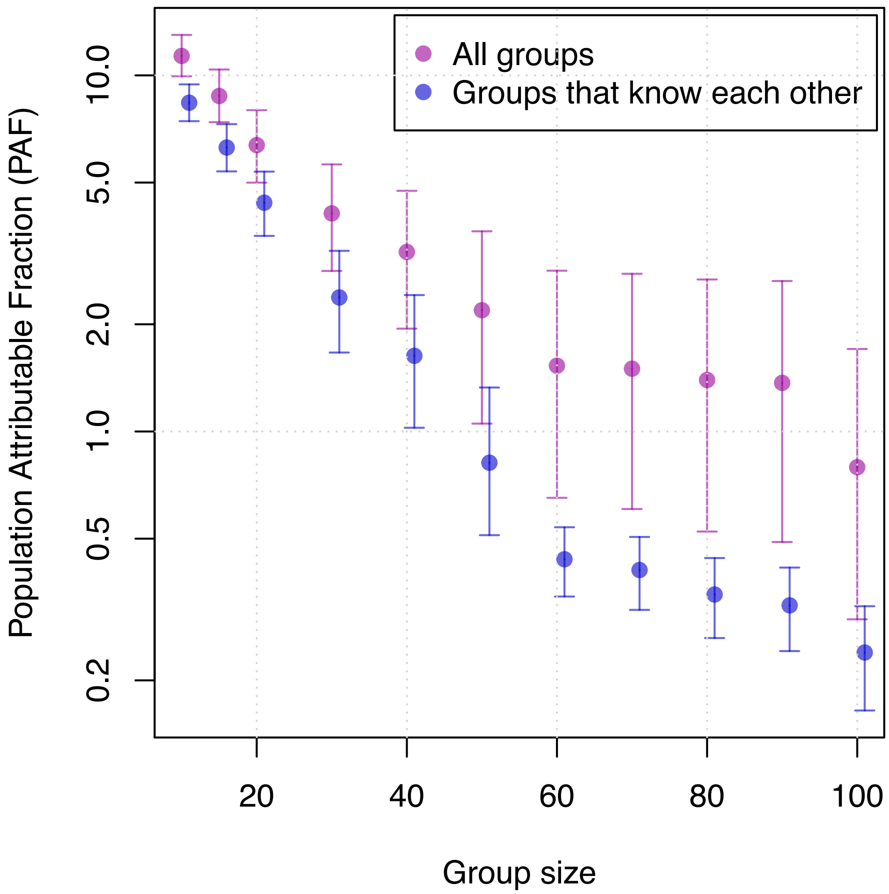

Figure 2: The Population Attributable Fraction (PAF) against group size. The filled black circles are all groups, empty blue circles are groups of people who are known to each other.