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Building relevance to improve public adherence to preventive measures against COVID-19 by reporting prevalence assessment from incidence numbers

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Incidence numbers (new cases) are communicated by the health authorities on a daily basis for all 98 Danish municipalities with a population range from 1,806 for Læsø to 623,404 for Copenhagen. Aarhus, the second largest city in Denmark, has a population of 349,983.

Since the epidemic peaked in early April at nearly 500 new confirmed cases per day, incidence numbers have been low . For comparison, an ongoing outbreak in Aarhus on Friday 7 August 2020 recorded 68 new confirmed cases. This is well below the peak and may be perceived as insignificant and be taken to mean that the epidemic is under control. Incidence is, however, defined as the number of new cases per time-unit, e.g. per day.

The disease prevalence, optionally provided as a prevalence proportion (% diseased in a population), may be a more appropriate figure to communicate as it allows the individual to directly assess the risk of coming into contact with a contagious person. The basic reproduction number, R0, is proportional to a) the risk of transmission during one contact, b) the number of contacts and c) the duration of infectiousness. The effective reproduction number, R, is the base in an exponential equation with the generation or round number in a chain of transmission as the exponent. R is influenced by the factors mentioned above, e.g. herd immunity, sanitizer and face-mask usage and social distancing (a), assembly bans and widespread voluntary reduction in social contacts (b) and quarantine measures (c). During the first wave of COVID-19, the government and health authorities in Denmark effectively implemented measures that reduced the reproduction number to well below one. The $R < 1$

is in constant jeopardy during a gradual reopening of society, which is needed for public life to return to normal.

Implementation of interventions to control an epidemic must be relevant and sensible in order for the public to gain confidence and to adhere to burdensome control measures. Events in recent weeks suggest that the public have relaxed their adherence as witnessed by a large public celebration of a football game in Aarhus and travel to high-risk countries. Furthermore, if the public's perception of the number of potentially infectious contacts is low, they may not adhere to precautions that reduce the risk of transmission during individual contacts. We suggest that prevalence and prevalence proportions may be more relevant at an individual level to better balance quality of life against risk of disease and death.

In basic epidemiology, the prevalence proportion equals the incidence rate times the duration of the infective state of the disease. For COVID-19, this number must be corrected to take into account the dark figure, i.e. the number of individuals who become infected but are not tested. For a well-described population like the inhabitants of Aarhus on 7 August 2020, the number of COVID-19-infected individuals may be calculated as:

Prevalence = disease duration x incidence x the dark figure.

Similarly, the number of infectious individuals may be calculated as:

Prevalence of infectious individuals = duration of infectiousness x incidence x the dark figure.

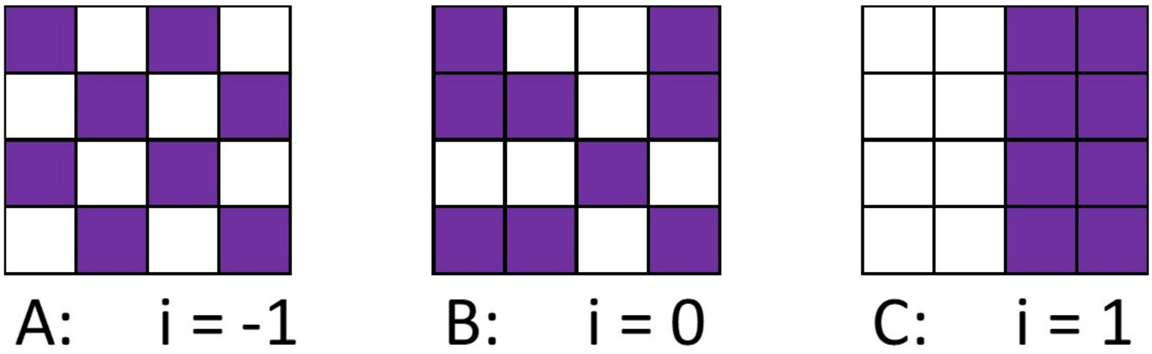

Figure 1. Moran's *i* for various spatial distributions of some geographical factor, e.g., number of individuals who have tested positive for SARS CoV2 distributed by zip code, municipality, region or country. "A" has a pattern where neighbouring areas to an area with a high prevalence of disease have taken action to avoid spread, e.g., through border closure between countries. In this case, there is a negative correlation between neighbouring areas and *i* becomes negative (approaches -1). "B" is a pattern of random distribution of disease, where incident cases cannot be traced back to a singular focus point. This may be the case in the Municipally of Aarhus. In this case, *i* approaches zero. "C" is a pattern where an outbreak is centred around a "hotspot", e.g. the outbreak among slaughterhouse workers in the Municipally of Ringsted, Region of Zealand, Denmark, where the incidence is not increased in neighbouring municipalities. In this case, *i* approaches one.

This simple relationship between incidence rate and prevalence proportion ideally requires a steady-state situation where the number of new cases is balanced by the number of cases leaving the infected population as either recovered or dead. Furthermore, the relationship may be imprecise if the incidence rate exceeds 5%.

The dark figure

The dark figure is dependent on test capacity, test activity and strategy, and changes during an epidemic.

On 7 April, the Danish Health Authority and the Statens Serum Institut published an estimated dark figure between 20 and 80 times the number of confirmed cases with an estimate for the Capital Region of 70 [1]. This estimate has subsequently been questioned and a recalculation has yielded a corrected dark figure in the 8-21 range. In a Danish study of blood donors, seroprevalence was 1.9%, corresponding to a total number of infected and previously infected individuals of 110,000 in Denmark by May 2020. In early May 2020, approximately 9,000 persons had tested positive for SARS-CoV-2 corresponding to a dark figure of 12 [2]. A Swiss seroprevalence study estimated a dark figure of 11.6 [3].

Prevalence and prevalence proportion

The incidence rate would be 68/349,983 = 0.019%. When communicating these data to the public, the risk of meeting a person with a positive SARS CoV2 PCR test performed today would be one in 5,263 person contacts.

The prevalence of people infected with SARS-CoV-2 in Aarhus on 7 August may be calculated as 12 x 68 x 12 = 9,792 using the dark figure from the seroprevalence studies and a conservative estimate of the period of infectiousness of 12 days. This conservative estimate is based on the fact that transmission of the disease may start already in the pre-symptomatic period, 2-3 days before symptoms [4], and in asymptomatic patients as well, and is at its highest during symptomatic disease, but unlikely after 7-10 days of symptoms [4]. These numbers correspond to a prevalence proportion of 2.8%. A recent study estimated that most individuals are infectious for around five days only [5], i.e. the number of infectious individuals may be 4,080 (5 x 68 x 12), yielding a prevalence proportion of 1.2%. Thus, the risk of meeting an individual who may transmit SARS CoV2 is in the range of one in 36-86 person contacts. These numbers and risks may be more relevant to consider when choosing to visit a night club, a football celebration or even a supermarket. This can be extended to leadership on micro- as well as macrolevel.

The considerations above are based on the presumption that incident cases represent the background population and not a delimited subgroup. The current outbreak in the Municipally of Aarhus, Denmark, is considered to be limited to hotspots surrounding the omnibus operations of the municipally, participants in an introductory course for economy students, a Somali minority group and participants in a football festivity. However, a case in a nursing home has also been reported and may reflect more random and widespread infectiousness in the municipality.

An improvement of the calculated prevalence estimate could be performed by controlling for the spatial autocorrelation of cases. Moran's i is a measure of spatial autocorrelation that has been used in medical epidemiology to determine if hot and cold spots of disease outbreaks exist [6]. It has been used to target prophylactic actions at street levels for outbreaks of hand-foot-and-mouth disease in Shantou, China [7]. If cases are distributed at random, Moran's i would be zero; and if cases are limited to a single hotspot, Moran's i would approach one. Multiplying the above calculated prevalence with (1- Moran's i) would yield control for the degree of "disease hotspotting" (Figure 1), and the equation becomes:

Prevalence of infectious individuals = duration of infectiousness x incidence x the dark figure x (1-Moran's i)

In summary, we suggest that communicating disease risk for an area, city or region should include numbers that are immediately understandable for the public. Prevalence is such a measure; and despite uncertainties in the estimation, it may build relevance for adherence to health authorities' recommendations.

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Conflict of interest: Disclosure forms provided by the authors are available with the full text of this article at

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